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NEW LIGHTS ON DIESEL-FUEL AIR POLLUTION

RESEARCH GRANTS

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HIGHLIGHTS OF SELECTED AIR POLLUTION RESEARCH GRANTS

Office of Research Grants

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
National Air Pollution Control Administration
Raleigh, North Carolina
May 1970

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National Air Pollution Control Administration Publication No. AP-70

CONTENTS

LIST OF PRINCIPAL INVESTIGATORS AND INSTITUTIONS v
INTRODUCTION 1
EFFECTS OF AIR POLLUTION ON HUMAN HEALTH, WELFARE, OR PRODUCTIVITY 3
Atmospheric Pollution by Aeroallergen Medical Phase 3
Biological Effects of Gaseous Ions 3
Clearance of Bacteria from Pulmonary Tissue 4
Sulfide Poisoning and Methemoglobinemia 5
Effect of Noxious Agents on Ciliated Epithelium 6
Mechanics of Mucus Flow and Ciliary Action 6
Toxicity of Terpenes as Air Pollutants 7
Airborne Fungal Spores 7
Atmospheric Pollution and Respiratory Disease 8
Pseudomonas in Tissue Cultures 9
EFFECTS OF AIR POLLUTION ON AGRICULTURE 11
Photochemical Effects of Oxidants on Plants 11
Biochemical Effects of Air Pollutant Oxidants 11
The Total Effect of Air Pollutants on Bearing Citrus 12
Effects of Dusts on Vegetation 13
HF–Air Pollution and Intermediary Metabolism 13
Response of Plant Fruiting to HF Fumigation 13
Air Pollution Effects on Plants 14
Cytogenetic Effects of Hydrogen Fluoride on Corn 14
Effects of Air Pollutants on Plant Growth 15
ECONOMIC AND POLITICAL STUDIES 17
Air Pollution and the Community Image 17
ANALYSES AND PHYSICOCHEMICAL INVESTIGATIONS 19
Photochemistry of Substances Present in Urban Air 19
Mechanisms of Photochemical Reactions in Urban Air 19
Selenium and Its Significance as an Air Pollutant 20
Mechanisms of Photochemically Initiated Oxidations 20
Bioengineering Aspects of Air Pollution 21
Behavior of Aerosol Particles 21
Controlled Source of Uniform Liquid Droplets 21
Formation and Decay of Atmospheric Aerosols 22
Composition of Lead Halide Pollution Aerosols 23
Influence of Aerosol Characteristics on Visibility 23
Primary Products of Photodissociation 25
DEVELOPMENT OF ANALYTIC METHODS AND EQUIPMENT 27
Generation and Decay of Small Ions 27
Particulate Sampling by Adhesive-Coated Material 27

Pollution Abatement by Process Gas Chromatography 28
Study of Atomizer Aerosol Generators 28
Study of Odor Components of Industrial Exhaust 28
Activation Analysis of Atmospheric Particulates 29
Portable Spectrometric Analyzer for Air Pollutants 29
METEOROLOGY 31
Travels of Airborne Pollen 31
Visible Species of Algae and Protozoa in the Atmosphere 31
Atmospheric Diffusion in the Inertial Subrange 32
Mesoscale Wind System Around the Great Lakes 32
Investigation of Ice Fog Problems 33
DESCRIPTION AND CONTROL OF AIR POLLUTION SOURCES 35
Formation of Oxides of Nitrogen During Combustion 35
Reduction of Polycyclic Aromatic Hydrocarbons 35
Particulate Emissions from Wood Waste 36
Carburetors – Reduction of Engine Exhaust Emissions 37
Chemical Aspects of Air Pollution from Kraft Pulping 37
Catalytic Mechanisms for Nitrogen Oxides Reduction 38
Interaction of Flue Gases with Carbon Surfaces 38
Crystal Structure Determination of Stable Ozonides 39
Gas Phase Kinetics of Kraft Mill Pollutants 40
Boundary Layer Flow in Electrostatic Precipitators 40
Engine Emission Reduction by Combustion Control 40
Reversible Metal Complexes with Air Pollutants 41
Air Transport of Pollutants to the Marine Environment 41
Fundamentals of Air Cleaning by Sorption Processes 42
COMMUNICATION 45
Manual of Methods for Sampling and Analysis of Air 45
Audiovisual Methods for Air Pollution Information 45
COMEX–Air Pollution Computer Research Project 46

LIST OF PRINCIPAL INVESTIGATORS AND INSTITUTIONS

Principal Investigator and Institution	Grant No.	Page
Ballenger, John V. Evanston Hospital Assoc.	AP 00321	6
Bolt, Jay A. University of Michigan	AP 00365	37
Boubel, Richard Oregon State University	AP 00348	36
Calvert, Jack G. Ohio State University	AP 00131	20
Charlson, Robert University of Washington	AP 00336	23
Darley, Ellis F. University of California	AP 00272	13
Douglass, Irwin B. University of Maine	AP 00383	37
Dugger, William University of California	AP 00040	11
Friedlander, S. K. California Institute of Technology	AP 00680	21
Goetz, Alexander Atmospheric Research Group	AP 00543	22
Gruber, Charles City of Cincinnati	AP 00370	27
Head, Murdock George Washington University Medical Center	AP 00415	45
Hendricks, Charles D. University of Illinois	AP 00511	21
Hewson, E. Wendell University of Michigan	AP 00380	32
Hill, A. Clyde University of Utah	AP 00452	15
Johnston, Harold University of California	AP 00104	19
Krueger, Albert P. University of California	AP 00002	3

Laurenzi, Gustave A.
New Jersey College of Medicine and Dentistry ..... AP 00005 4

Leffland, Knud W.
University of Southern California ..... AP 00508 46

Long, Ronald
University of Birmingham, England ..... AP 00323 35

Low, M. J. D.
New York University ..... AP 00669 42

MacCready, Paul, Jr.
Meteorology Research, Inc. ..... AP 00359 32

McAtee, James L., Jr.
Baylor University ..... AP 00422 39

McFarland, A. R.
University of Minnesota ..... AP 00136 27

Mathews, A. R.
University of Michigan ..... AP 00001 3

Meyer, Wolfgang E.
The Pennsylvania State University ..... AP 00560 40

Miller, Calixtus E.
Manhattan College ..... AP 00362 6

Miller, Gene W.
Utah State University ..... AP 00276 13

Mohamed, Aly H.
University of Missouri ..... AP 00586 14

Mudd, J. Brian
University of California ..... AP 00071 11

Murray, F. E.
British Columbia Research Council ..... AP 00532 40

Nolan, William J.
University of Florida ..... AP 00672 41

Ogden, Eugene C.
The University of the State of New York ..... AP 00081 31

Ohtake, Takeshi
University of Alaska ..... AP 00449 33

Pack, Merrill R.
Washington State University ..... AP 00341 13

Peters, Max S.
University of Colorado ..... AP 00388 38

Pitts, J. N., Jr.
University of California ..... AP 00109 19

Post, Roy G.
University of Arizona ..... AP 00519 29

Rankin, Robert E.
West Virginia University ..... AP 00460 17

Sage, B. H.
California Institute of Technology ..... AP 00107 35

Schaer, Michael
Montana State University ..... AP 00475 28

Schlichting, H. E., Jr.
North Texas State University ..... AP 00137 31

Sherwin, Russell P.
University of Southern California ..... AP 00607 9

Sholtes, Robert
University of Florida ..... AP 00493 21

Smith, George T.
University of Nevada ..... AP 00545 7

Smith, Roger P.
Dartmouth College ..... AP 00260 5

Snell, Robert E.
Hospital for Sick Children ..... AP 00484 8

Soo, S. L.
University of Illinois ..... AP 00541 40

Stern, A. C.
University of North Carolina at Chapel Hill ..... AP 00256 45

Thompson, C. Ray
University of California ..... AP 00270 12

Trieff, Norman
Drexel Institute of Technology ..... AP 00501 28

Vaska, Lauri
Clarkson College of Technology ..... AP 00574 41

Walker, P. L.
The Pennsylvania State University ..... AP 00406 38

Weber, Darrell J.
University of Houston ..... AP 00554 7

West, Philip W.
Louisiana State University ..... AP 00724 20

Whitby, K. T.
University of Minnesota ..... AP 00480 28

Williams, David
University of Florida ..... AP 00591 29

Winchester, John W.
University of Michigan ..... AP 00585 23

Wilson, Kent R.
University of California ..... AP 00675 25

Wood, Francis A.
The Pennsylvania State University ..... AP 00436 14

INTRODUCTION

Air pollution is already a serious threat to health, and our continuing urban and industrial growth is rapidly increasing the pollution of the air we breathe.

The United States Congress reacted to the critical air pollution problem by passing, in 1963, the Clean Air Act, which gives to the Federal government the authority to establish major research and development programs. In 1965 and again in 1967, the Clean Air Act was amended to broaden this authority and to stimulate both control programs and research.

The research grant program capitalizes on the expertise and imagination of scientists in universities and other nonprofit research institutions. In 1960 the Office of Research Grants of the National Center for Air Pollution Control assumed from the National Institutes of Health the responsibility for administering research grants in air pollution. Since that time, the number of research grants has grown from 22 in fiscal year 1961 to nearly 220 in fiscal year 1968. Funds dispersed in these grants have increased from $456,237 in fiscal year 1961 to nearly $7,500,000 in fiscal year 1968. The continuing increase in the number of applications for research grants reflects the growth of national interest in abatement of air pollution and of appreciation for the challenging technical problems involved.

The National Air Pollution Control Administration is concerned with all aspects of research and development in the causes, effects, extent, prevention, and control of air pollution as it affects health, welfare, and productivity. The research grant program covers eight major areas: human health effects, agricultural effects, socioeconomic and political studies, analyses and physicochemical investigations, development of analytic methods and equipment, meteorology, air pollution source control, and communications. Research in these and closely related areas increases our understanding of the fundamental nature and the complexity of the air pollution problem.

Research grant support, awarded to universities, foundations, and other non-Federal institutions throughout the United States, provides an excellent opportunity for scientists to challenge the difficult technical problems in prevention and control of air pollution. Research grants are the primary responsibility of the Office of Research Grants, NAPCA.

This booklet is intended to present to the public as well as the scientific community some of the recent accomplishments of the research grant program and some of the ways that tax dollars are being used to help solve air pollution problems. It is not a comprehensive account of all projects, but it does present highlights of selected, representative studies. Because of space limitation many equally worthwhile and interesting research projects cannot be included in this first publication; however, future publications will include other projects as well as additional results of continuing projects. These highlights are meant to improve communications among investigators and to provide information to the interested public.

Since research is a continuing process, the reader must recognize that the picture changes progressively during the period that any report is being generated; therefore, the highlights contained in this report are not completely current.

Under the grants program the investigator not only submits annual progress reports to the Office of Research Grants, but as expeditiously as possible publishes the material in the open scientific literature, where it is available to the scientific community. Individuals interested in the results of specific research are encouraged to communicate directly with the investigator.

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EFFECTS OF AIR POLLUTION ON HUMAN HEALTH, WELFARE, OR PRODUCTIVITY

ATMOSPHERIC POLLUTION BY AEROALLERGEN MEDICAL PHASE

Kenneth P. Mathews
University of Michigan, Ann Arbor, Michigan

At the University of Michigan Medical Center, medical researchers, botanists, and meteorologists are investigating the production and dissemination of living and non-living particles in the air and the human allergic response when these particles are inhaled. By thorough examination of ragweed pollinosis, Dr. Kenneth P. Mathews and his associates are seeking knowledge of basic relationships having wide applicability to a variety of aeroallergens.

Human subjects sensitive to ragweed were studied during three consecutive pollen seasons. Multiple daily clinical observations, objective ventilatory tests, studies of blood and nasal cytology, and subjective reports were used to define a broad seasonal parallelism of pollen concentrations and symptom severity. The study has demonstrated that significant symptoms of rhinitis and asthma tend to persist into periods of declining pollen levels and that diurnal patterns of symptom severity correlate poorly with concurrent or immediately preceding pollen concentrations.

Other studies by this research team revealed fewer allergic manifestations in families of non-native university students than in native groups. Over several years, the incidence of atopic allergy among foreign-born students was observed to rise and finally equal that of native-born students. This observation emphasizes the importance of exposure to potent allergens in revealing a latent capacity for allergic response.

Several improved techniques for manipulating immunoglobulins have been developed in the course of these studies. One technique is used to assess the properties of the human skin sensitizing antibody (SSA). The studies have produced strong evidence of stoichiometric combination of SSA with specific antigens and have confirmed the incapacity of normal human serum components to block passive transfer reactions involving SSA.

The importance of a multiplicity of sensitivities in determining the symptoms of atopic persons led to the development of comprehensive programs using volumetric techniques to sample for viable and non-viable atmospheric particles. Using newly developed samplers, the investigators collected volumetric prevalence data for many types of viable and non-viable particles in the air, some of which have previously received little attention but which may be important to public health.

BIOLOGICAL EFFECTS OF GASEOUS IONS

Albert P. Krueger
University of California, Berkeley, California

Dr. Albert P. Krueger of the University of California School of Public Health, using advanced instrumentation, is investigating the possible biological effects of small air ions. Dr. Krueger and his associates have found that physiological functions are indeed responsive both to excessive numbers of ions and to their virtual absence. Some findings of their studies are:

1. High concentrations of small positive and negative ions increase the death rate of some types of microorganisms suspended in small droplets of water.

2. Small positive ions in excess inhibit the efficiency of the respiratory tract mucus escalator

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responsible for removing inhaled particles and increase vulnerability of the tissues to mechanical trauma.

3. Negatively ionized air reverses the changes induced by positive ions.

4. The powerful neurohormone 5-hydroxytryptamine (5-HT) has an important role in air ion action on the respiratory tract. Positive CO_2 ions bring about an increase in tissue levels of 5-HT. This neurohormone, in turn, directly influences many basic physiological functions, e.g., permeability of the small blood vessels and rate of respiration. Negative O_2 ions reduce the tissue levels of 5-HT by speeding the rate at which it is oxidized and, in consequence, neutralize the effects of CO_2+ ions.

5. Positive or negative O_2 ions markedly stimulate the growth of higher plants while positive or negative CO_2 ions inhibit germination and growth, seriously curtail the formation of chlorophyll, and devitalize the young seedlings.

6. Reduction of the total small ion content of the ambient air to approximately 3 percent of the normal level inhibits growth of plants and causes them to develop very soft leaves and to lack normal rigidity.

7. Exposure of silk worm eggs to high densities of positive or negative ions accelerates hatching and the onset of spinning and increases the rate of larval growth, the production of several of the ion-containing enzymes, and the weight of the cocoons.

Dr. Krueger points out that although information about the biological effects of air ions is far from complete, his research finding might have practical applications. For example, the average electrical space heater and the ordinary electrostatic precipitator are excellent generators of positive ions. With a normal level of .05 percent CO_2 in the ambient atmosphere, the direct formation of CO_2+ ions and their indirect production by charge transfer could lead to an ionic imbalance of potential physiological significance. Higher CO_2 levels, frequently occurring in submarines, meeting halls, etc., increase the chances of CO_2+ ion formation constituting a health hazard.

Positive or negative CO_2 ions can be formed in concentrations sufficient to affect plant growth also, for CO_2 concentrations in the ambient air are artificially raised at times in whole geographic areas where a variety of ionization energy sources exists.

Dr. Krueger reports that laboratory and field evidence now available indicates that environmental engineers of the future will include specifications for air ion density and ionic balance in their definitions of optimal conditions for health.

CLEARANCE OF BACTERIA FROM PULMONARY TISSUE

Gustave A. Laurenzi
New Jersey College of Medicine and Dentistry, Jersey City, New Jersey

Dr. Gustave Laurenzi is investigating the mechanisms whereby the normal respiratory tract is able to rid itself of bacteria and the factors which upset these mechanisms so that bacteria are able to take hold, colonize, and cause bronchial infection. Studies of human respiratory action or response are basic to establishment of air quality standards.

His studies with humans at the New Jersey College of Medicine and Dentistry have revealed that the normal lower respiratory tract has a remarkable capacity to clear bacteria and to remain sterile despite constant bacterial challenge through inhalation and natural aspiration. In the bronchitic, however, impairment of this function allows respiratory pathogens to reside in his lower respiratory tract and to

colonize during acute chest illnesses. Such information helps the investigators to reconstruct the role of bacterial infection in the acute exacerbation. Evidence indicates that a non-bacterial bronchial insult (viral infection, air pollution, etc.) may set up circumstances which allow the parasitic bronchial pathogens to colonize and produce secondary bronchopulmonary infection with all its serious sequelae. This information further delineates the role of antibiotic therapy.

A method has been developed for measuring quantitatively the clearance of bacteria from the lungs of mice implanted by exposure to bacterial aerosols. Bacterial clearance is rapid: 45 percent of bacteria deposited disappear within 1 hour, and 95 percent within 6 hours. The method serves as a bioassay for determining the effect of intrinsic conditions, meteorological changes, and respiratory irritants.

Dr. Laurenzi's quantitative studies have shown that bacteria removal by the respiratory tract is adversely affected by smoke inhalation, alcohol, cortisone, barbiturates, hypoxia, endotoxin. In addition, he found that specific pathogen-free mice, free of ordinary intestinal pathogens, are resistant to the deleterious effect of smoke. The presence of these ordinary gram-negative organisms predisposes to smoke interference with pulmonary disposal of inhaled bacteria.

Investigators also have observed that oxygen inhalation has a deleterious effect on tracheo-bronchial mucus flow and thereby interferes with the clearance of secretions. In animals exposed to 10 percent and 100 percent oxygen sequentially, mucus flow rate was reduced 90 percent. Epinephrine and digitalis greatly stimulated mucus flow; aerosolized racemic epinephrine, intramuscular epinephrine, and therapeutic doses of intravenous G-strophanthin enhanced nasal flow and prevented and reversed adverse hyperoxic and hypoxic effects. These results suggest that the mucociliary system functions optimally at ambient oxygen tension.

In studies of the capacity of alveolar macrophages for defending the respiratory tract against foreign particles and bacterial infections, macrophage yield significantly increased during 1 to 4 hours smoke exposure. Smoke did not reduce macrophage viability or alter macrophage mobilization following an airborne bacterial challenge.

SULFIDE POISONING AND METHEMOGLOBINEMIA

Roger P. Smith
Dartmouth College, Hanover, New Hampshire

Dr. Roger P. Smith, investigating methemoglobin and sulfide poisoning at Dartmouth Medical School, recognized that hydrogen sulfide (a frequent air pollutant) can be a violent poison producing many symptoms in common with cyanide gas. Exploring the possibility that some treatment methods might work against poisoning by either gas, he has discovered at least one emergency procedure of potential value.

In animals poisoned by hydrogen sulfide, methemoglobin avidly traps this poison and prevents it from attacking vital sites in the brain. Sulfide trapped by methemoglobin can either undergo further transformation to harmless products or be slowly released at a rate tolerable to the animal. Once it has served this purpose, methemoglobin is spontaneously reconverted to oxyhemoglobin in the blood. Although this treatment is still untried in humans, human methemoglobin injected into animals protects them as well as methemoglobin generated in their own blood.

Dr. Smith's research has revealed other information about methemoglobin in addition to its potential value as an emergency procedure in acute hydrogen sulfide poisoning. Since some kinds of methemoglobin can trap more sulfide than cyanide, previously unrecognized changes probably occur when oxyhemoglobin is converted to methemoglobin. Moreover, methemoglobins generated by different chemicals appear to have different chemical properties. The systems that spontaneously reverse a methemoglobinemia have been found to reverse some changes, but not necessarily all. Eventually, such research may contribute to better means of treating methemoglobinemia as well as hydrogen sulfide poisoning.

EFFECT OF NOXIOUS AGENTS ON CILIATED EPITHELIUM

John V. Ballenger
Evanston Hospital Association, Evanston, Illinois

Dr. John V. Ballenger is investigating the relationship of the mucociliary cleansing mechanism of the human respiratory tract to selected air pollutants. The ciliary activity is quantitatively assayed by a rotating explant method.

Dr. Ballenger's work on the ciliostatic property of nicotine has produced several findings. A considerable increase in the ciliostatic property of nicotine was observed when the ciliated explant was first infected with 10,000 EID_{50}'s of influenza B virus. Two hours after the nicotine perfusion (0.3-0.4 percent by weight of oxidized nicotine), the rotating speed of the infected explant was 41 percent less than that of the nicotine perfused, uninfected explant. From the clinical point of view this suggests that air pollutant exposure may impair the mucociliary cleansing mechanism of the respiratory tract more in an individual with a myxovirus infection than in one free of the virus infection.

Recent experiments in heat inactivation of influenza B virus showed that exposure to 56°C for 1 hour does not inactivate the ciliostatic effect of the virus. The investigator found that adsorption of heat inactivated virus by guinea pig erythrocytes removed the ciliostatic substance associated with the virus particle. High speed centrifugation (18,000 rpm for 1 hour) of the heat inactivated virus produced indications that the ciliostatic effect resided primarily in the virus particle.

Rotation speeds of human ciliated explants were increased by perfusion with nicotinamide adenine dinucleotide (NAD) and with adenosine diphosphate (ADP). Perfusion with 100 mg% NAD was followed at the end of 45 minutes by an increased rotation speed of 31.5%. Perfusion with 100 mg% of ADP produced a 35% increase in speed within 15 minutes. When 50 mg% each of NAD and ADP were perfused, an increased speed of 52% was recorded almost immediately. The investigators concluded that in vitro both NAD and ADP caused increased activity of human respiratory cilia but the combination of 50 mg% of each caused a greater increase in speed than either alone.

MECHANICS OF MUCUS FLOW AND CILIARY ACTION

Calixtus E. Miller
Manhattan College, New York, New York

Dr. Calixtus E. Miller is investigating the effects of definite amounts of atmospheric pollutants upon vital tissues of the body. Knowledge gained in this project might be used to determine a lower limit of air pollutants which will not appreciably damage the mammalian system.

At the Rheological Mechanics Laboratory of Manhattan College, mechanical apparatus analogous to the mammalian mucociliary system was constructed and has been in operation for 2 years. The apparatus, called a Rheociliometer, has enabled Dr. Miller and his associates to measure and control the speed of particulate matter and other foreign bodies. They have shown the speed to be a function of the frequency and amplitude of the beating mechanical cilia and have demonstrated the initiation of the flow of a Newtonian fluid to be due only to the phasing of the ciliary beat.

Dr. Miller's group performed other experiments to predict the mechanical features of the flow which may relate to the mammalian system. They found that the ratio of the frictional forces to the inertial forces was a function of the Reynolds number. This finding indicates that the Navier-Stokes equations and the continuity equation form the set of differential equations that must be solved to establish the fluid dynamics of the entire system.

A viscoelastic fluid similar to mucus has been developed in the laboratory and is now used in all

experiments previously carried out with Newtonian liquids. The ratio of the velocity of particulate matter to the wave velocity of ciliary beat was found to be a linear function of the Reynolds number. This result later was correlated with the mammalian mucociliary system.

After mechanical features of flow in the Rheociliometer were established and described functionally, the investigators studied the relationship of these flow features to the mucociliary system of the cat's trachea. Applying improved surgical techniques first developed by Dalhamn in Sweden, they measured the frequency and wavelength of ciliary beat *in vivo*. They found that the ratio of the velocity of particulate matter embedded in the mucus to the wave velocity of the ciliary beat was a linear function of the Reynolds number. The linear function had different slopes for different animals, and the family of lines drawn for several animals is directly correlated with the linear function obtained with the Rheociliometer. The investigators thus developed a theory of mucociliary system response to variations in frequency of ciliary beat and in depth, viscosity, and density of mucus.

With this theory, one can predict the action of toxic materials on the mucociliary system in terms of these biomechanical factors. Using SO_2 as a toxic material, Dr. Miller has validated the theory. His experiments indicate that chemical changes took place in the lung system at the area in which gas is exchanged between the alveolar and vascular systems.

The uniqueness of the research lies in the fact that effects of pollutants on vital tissues are being correlated with the effects on the mechanism of the mucociliary system. This research should yield needed, basic physiopathological knowledge.

TOXICITY OF TERPENES AS AIR POLLUTANTS
George T. Smith
University of Nevada, Reno, Nevada

Research by Dr. George T. Smith at the University of Nevada's Desert Research Institute suggests that terpene, the hydrocarbon that gives pine trees their smell and the Blue Ridge Mountains their color, may actually cause serious respiratory diseases such as emphysema and asthma. In one experiment, post mortem studies of cows forced to breathe terpene 3 to 7 days through a tube inserted in their nostrils, confirmed that all had emphysema, even though forced to breathe the terpenes only an hour a day. More work is needed to definitely link asthma and emphysema in man to exposure to terpenes; however, statistics do show a correlation between increased hospital admissions from asthma and high levels of terpenes in the air.

Dr. Smith and his associates first became suspicious of the role of terpenes in bovine emphysema, which long has been a common problem for ranchers in the Southwest. The cause of this condition, frequently called the "grunts" because of labored breathing by the affected cows was never clear, but it ocurred in the fall when the cows were brought down into the valley where terpene concentrations were heavier. In the summer, grazing in the Sierra Nevada mountains where there was little terpene in the air, the cows never seemed to be troubled.

The research group is now planning a pure air chamber for humans and cows in order to investigate the effects of varied atmospheres in altering symptoms.

AIRBORNE FUNGAL SPORES
Darrell J. Weber
University of Houston, Houston, Texas

The presence of fungal spores in the atmosphere is of serious concern because many of these spores are inhaled and deposited in the lungs of humans and animals. Repeated exposure to certain fungal spores

may result in allergic reactions with serious discomfort in some individuals. Furthermore, the waxy coatings on these spores contain hydrocarbons which may be carcinogenic. Dr. Darrell J. Weber, of the University of Houston, is investigating these waxy coatings to determine their effects in air pollution, allergic reactions, and diseases.

The spore populations in the atmosphere in various parts of Texas were sampled with a continuously operating spore trap. The major spore types found in the Houston area in very high concentrations were *Aspergillus, Alternaria, Cladosporium,* and *Fusarium;* the major spore type found in the El Paso area was *Alternaria.* With continuing sampling and statistical analyses investigators will estimate the populations of spores in the atmosphere and their role in air pollution over large cities.

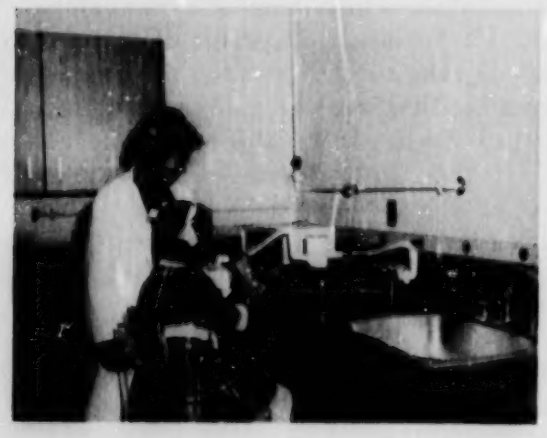
The waxy materials from spores of several types were extracted by lipo solvents and fractionated into 3 fractions with a silica gel column. Then the fractions were analyzed with a gas chromatograph using a capillary column. Unknown compounds that were separated on the gas chromatograph were characterized with a gas chromatograph-mass spectrometer combination.

The investigators found that the hydrocarbon pattern was distinct for each species of fungi analyzed and that the odd numbered hydrocarbons predominated in every case. The predominant n-alkane peaks were C_{27} for *Ustilago maydis,* C_{29} for *Puccinia graminis,* C_{29} and C_{31} for *Ustilago agropyri,* C_{27} and C_{31} for *Ustilago nuda,* C_{29} and C_{31} for *Ustilago avenae,* and C_{29} for *Sphacelotheca reiliana.* All three fractions of *Ustilago maydis* were analyzed. The hydrocarbon fraction contained predominantly C_{25}, C_{27}, and C_{29} n-alkanes. The benzene fraction contained natural methyl esters, predominantly C_{16} through C_{20}, of saturated and unsaturated fatty acids. This was the first report of naturally occurring methyl esters in fungi. The methanol fraction contained free fatty acids ranging in carbon number from C_{12} through C_{20}. In both the free fatty acids and the natural methyl esters, the distribution patterns of the carbon skeletons were similar, and the predominant compounds had even-numbered carbon chains. Investigators are now attempting to determine the biosynthesis of the waxy materials in fungi.

ATMOSPHERIC POLLUTION AND RESPIRATORY DISEASE

Robert E. Snell
Hospital for Sick Children, Washington, D. C.

Dr. Robert Snell, at the Hospital for Sick Children in Washington, D. C., is working to define the role of environmental agents such as air pollutants in the cause and perpetuation of asthma. The researchers are



Laboratory adjacent to the environmental control unit

using a 600-square-foot environmental control unit in which they can carefully control and monitor atmospheric pressure, temperature, and humidity. The unit includes a capability for strict control and variation of the gaseous and particulate constituents of the atmosphere. A child can reside in this unit for

up to 1 month, carrying out all his daily activities in the unit. Changes in the child's status during this period are observed by means of repeated measurements of respiratory function.

During construction of the environmental control unit, Dr. Snell and his associates have been investigating emotional factors that may affect test results and training technical personnel who will be in daily close contact with the children.

Investigators hope to establish the concentration-time relationships necessary to produce changes in respiratory function in an individual with pulmonary disease who is exposed to specific environmental variations. Such information is urgently needed for establishment of rational air quality criteria. The information obtained also is valuable in the diagnosis and care of the children within the unit.

Shown here is the interior of the environmental control unit at the Hospital for Sick Children in Washington, D. C. The unit is being developed by Dr. Robert Snell under a research grant to the hospital.

PSEUDOMONAS IN TISSUE CULTURES
Russell P. Sherwin
University of Southern California, Los Angeles, California

At the University of Southern California, Dr. Russell P. Sherwin is investigating the response at the cellular level of lung tissues exposed to air pollutants, in particular the interactions between bacteria (and their L forms) and leucocytes. Dr. Sherwin found that macrophages and alveolar wall cells increase remarkably in response to experimentally applied nitrogen oxide. Investigators have measured this response which, they believe, has potential as a biologic indicator for air pollution.

In another study, Dr. Sherwin found that nitrogen dioxide causes macrophages to be attracted to epethelial cells. Both the frequency of epithelial cell-macrophage interaction and the number of macrophages present on any one epithelial cell increase. This phenomenon may be another useful biologic indicator for various types of insult to the lung.

up to 1 month, carrying out all his daily activities in the unit. Changes in the child's status during this period are observed by means of repeated measurements of respiratory function.

During construction of the environmental control unit, Dr. Snell and his associates have been investigating emotional factors that may affect test results and training technical personnel who will be in daily close contact with the children.

Investigators hope to establish the concentration-time relationships necessary to produce changes in respiratory function in an individual with pulmonary disease who is exposed to specific environmental variations. Such information is urgently needed for establishment of rational air quality criteria. The information obtained also is valuable in the diagnosis and care of the children within the unit.

Shown here is the interior of the environmental control unit at the Hospital for Sick Children in Washington, D. C. The unit is being developed by Dr. Robert Snell under a research grant to the hospital.

PSEUDOMONAS IN TISSUE CULTURES
Russell P. Sherwin
University of Southern California, Los Angeles, California

At the University of Southern California, Dr. Russell P. Sherwin is investigating the response at the cellular level of lung tissues exposed to air pollutants, in particular the interactions between bacteria (and their L forms) and leucocytes. Dr. Sherwin found that macrophages and alveolar wall cells increase remarkably in response to experimentally applied nitrogen oxide. Investigators have measured this response which, they believe, has potential as a biologic indicator for air pollution.

In another study, Dr. Sherwin found that nitrogen dioxide causes macrophages to be attracted to epethelial cells. Both the frequency of epithelial cell-macrophage interaction and the number of macrophages present on any one epithelial cell increase. This phenomenon may be another useful biologic indicator for various types of insult to the lung.

EFFECTS OF AIR POLLUTION ON AGRICULTURE

PHOTOCHEMICAL EFFECTS OF OXIDANTS ON PLANTS

William Dugger
University of California, Riverside, California

Investigating the photochemical effects of oxidants on plants, Dr. William Dugger found that the sulfhydryl (SH) content of young primary leaves was considerably higher than that of leaves of plants 14 to 17 days old. He also found that the difference in SH content between plants grown under normal photoperiod and those that had been in the dark for 24 hours was greater in the younger, more susceptible tissue. The plants lose their susceptibility to peroxyacetyl nitrate (PAN) at 14 days, and at this stage there is little, if any, difference in the SH contents of the light and pre-dark treated tissues. The SH content of 10-day old plants pretreated with 24 hours darkness increases when the plants are returned to the light and reaches a maximum after 3 hours. Previous results have shown that plants given a 24-hour dark period become sensitive to PAN again after a light period of 3 hours.

Plant damage depends upon both the intensity and the wavelength of the light. When exposed to PAN in the dark, plants grown under high light intensity will be damaged while plants grown under low or moderate light intensities will not be damaged. Irradiation of the plants with light of 660μ wavelength during the 15-minute exposure period results in typical PAN damage regardless of the light intensity under which the plants are grown. If, however, the plants are exposed simultaneously to 660μ and 700μ monochromatic light with the PAN treatment, they will not be damaged. Radiant energy of 700μ partially reverses the susceptibility to dark PAN damage of bean plants grown at high light intensity. Thus, radiant energy of 700μ partially protects plants against PAN damage.

Dr. Dugger found that leaf tissue from lemon seedlings fumigated with ozone takes up oxygen faster than the tissue from control plants. This increased uptake occurs several weeks prior to the onset of visible damage. The leaves show a considerable increase in reducing sugar content and a decrease in starch content. These two changes may be related and may indicate either a stimulation of starch hydrolysis or an inhibition of starch synthesis from hexose. The increase in reducing sugars may account for the increase in respiration observed in ozone treated tissue.

In other experiments by Dr. Dugger's group, uniformly labeled C^{14}-glucose was supplied to leaf discs from both ozone treated and control lemon seedlings in order to determine the effect of ozone on cell permeability. In ozone treated tissues, the permeability to exogeneous sugars and the rate of decarboxylation of the labeled glucose increased considerably. Other experiments using specifically labeled C^{14}-glucose showed that ozone did not induce changes in the pathway of glucose catabolism but did induce a two-to-threefold increase in the rate of decarboxylation or utilization of the glucose. Increased permeability to glucose was found to be the first effect of ozone fumigation preceding the increase in the decarboxylation of glucose. These metabolic changes caused by ozone fumigation may account for the citrus leaf drop observed in air containing low levels of oxidants. The increased decarboxylation stimulated by low levels of ozone over an extended period of time, however, might cause a premature starvation and subsequent abscission of citrus leaves.

BIOCHEMICAL EFFECTS OF AIR POLLUTANT OXIDANTS

J. Brian Mudd
University of California, Riverside, California

In his research on "Biochemical Effects of Air Pollutant Oxidants," Dr. J. Brian Mudd determined the primary reactions of ozone and peroxyacetyl nitrate with components of the living cell which give rise to toxic responses.

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Compounds that play a catalytic role in metabolism were chosen for the study of chemical reactions of air pollutant oxidants. The enzymes and co-enzymes are in this category since they are responsible for the transformation of many thousands of substrate molecules but remain unchanged themselves. Thus, the inactivation of one enzyme molecule prevents the metabolism of thousands of substrate molecules while the destruction of one of the substrate molecules would have a negligible effect.

Thorough investigation of the reaction of peroxyacetyl nitrate with thiol groups has revealed two reactions: (1) oxidation is always observed and (2) acetylation is sometimes observed. The experiments show that enzymes which do not require free thiols for their activity are resistant to peroxyacetyl nitrate. Enzymes which alternate between thiol and disulfide forms are susceptible in the thiol form and resistant in the disulfide form.

Studies of the reactions of ozone have concentrated on the reactions with amino acid residues. The oxidation of these residues is much less specific than that of peroxyacetyl nitrate. The susceptible amino acid residues in decreasing order are: cysteine, methionine, tryptophan, tyrosine, histidine, cystine, and phenylalanine. Decrease in the biological activity of proteins after treatment with ozone is correlated with the oxidation of one or more of these amino acid residues. Dr. Mudd has started physiological experiments to learn whether the reactions with proteins are really relevant.

The subcellular particles to be studied, chloroplasts and mitochondria, are complex lipoprotein systems, and researchers do not yet know whether the protein component is attacked before the lipid component. If one of these is much more susceptible than the other, this fact will be important in the design of a suitable chemical antagonist. The production of such an antagonist would immediately benefit agriculture and might eventually benefit human health.

THE TOTAL EFFECT OF AIR POLLUTANTS ON BEARING CITRUS

C. Ray Thompson
University of California, Riverside, California

The objective of Dr. Thompson's project is to determine whether and how much air pollutants are damaging citrus crops. Dr. Thompson first focused on lemon trees near Upland, California, and later added navel orange trees to the project. Initially, he enclosed 24 lemon trees individually in plastic-covered greenhouses which could be provided with various fractions of the atmosphere, and he divided the trees into 6 treatment groups of 4 trees each. Levels of total oxidants, levels of fluoride, and temperatures were recorded in the air continuously.

Within a few weeks after the experimental treatments began, Dr. Thompson observed that trees receiving filtered air required more water than those getting ambient air. Measurement of apparent photosynthesis on the trees showed that those receiving filtered air used more carbon dioxide than those in ambient (smoggy) air. Fluoride caused no measurable effect.

Preliminary evaluation of leaf drop, fruit drop, and fruit yield indicates that trees receiving ambient air have greater leaf drop (up to 30%) and yield less fruit than trees receiving carbon-filtered air. The average yield in ambient air is often only one-half of that in clean air. Fruit size, however, is not affected. Photochemical smog, principally from auto exhaust, seems to be causing most of this damage. Atmospheric fluoride is present in such small concentrations that it has no measurable effect.

Some of the early fruit drop of navel oranges might be overcome by the antioxidants N,N'-diphenyl-p-phenylenediamine and Ni-di-N-butyldithiocarbamate. Studies of the mechanism of this reaction continue.

EFFECTS OF DUSTS ON VEGETATION

Ellis F. Darley
University of California, Riverside, California

Investigating the effects of dusts on vegetation, at the Statewide Air Pollution Research Center, Dr. Ellis F. Darley has been working on methodology to determine the effects of certain cement-kiln dusts. Short-term experiments (dusting 10-day old plants for 2 to 3 days) have shown definitely that harmful effects can be expected only when dusted leaves are wet with dew. Dusts from different sources vary in this respect, but the relationship of chemical composition to injury has not yet been determined.

Large chambers which permit dusting plants to maturity (approximately 60 days) have been developed. The first experiment with these chambers showed no measurable effect on plant growth when the dust was applied to dry leaves on alternate days. Dr. Darley has built a dew chamber large enough to hold large plants in order to examine the effect of dew formation at regular periods during dusting.

HF-AIR POLLUTION AND INTERMEDIARY METABOLISM

Gene W. Miller
Utah State University, Logan, Utah

Before his investigation, most plants were thought to be unable to synthesize fluoroacetate and flourocitrate; Dr. Gene W. Miller, however, has now demonstrated that fluorocitrate and fluoroacetate accumulate in common cultivated plants which are exposed to atmospheric chloride or fluoride in the growth medium. Fluoroacetate is extremely toxic to animals since they convert it to fluorocitrate. Fluorocitrate is lethal to most animals at concentrations of 0.1 to 5mg fluorocitrate per 1kg body weight.

The detection of these toxic compounds in forage crops in the vicinity of industrial areas is very significant. Fluoride injury to grazing animals may be attributable in part to organic fluoride. Dr. Miller is now experimenting to determine toxic levels over a long period of feeding and is considering possible effects on humans of fluoroorganic levels found in cultivated crops.

RESPONSE OF PLANT FRUITING TO HF FUMIGATION

Merrill R. Pack
Washington State University, Pullman, Washington

Dr. Merrill R. Pack is evaluating the effects of hydrogen fluoride (HF) on plant fruiting in 12 plant species representing a cross section of the major crop plants grown primarily for fruit or seed. In initial tests, to determine the effects and the plants affected, Dr. Fack subjected plants to unrealistically severe continuous exposure to 10 to 15 μg per cubic meter throughout the life of the plants or from at least a week prior to flowering. The plants also were grown at a low calcium level (40 ppm) since such levels were found to favor maximum response to HF.

The most common effect of the HF was reduction of the number of seeds produced and consequent distortion of fruit due to lack of fruit development around the sterile ovules. These responses occurred in bean, pea, tomato, and strawberry plants. Sweet corn, grain sorghum, and pepper failed to produce any fruit under continuous exposure to HF at about 10 μg F per cubic meter. Growth of the sweet corn ears was arrested prior to silk emergence, and the sorghum produced no heads. On pepper, flowering was delayed and reduced, and the flowers fell off without producing fruit.

An experiment with tomatoes revealed the relationship between calcium nutrition and the effect of HF on plant fruiting. Plants growing at four levels of calcium nutrition (40, 80, 120, and 220 ppm) were

exposed continuously to HF at 6 μg F per cubic meter. The tomato fruits were smaller and contained less seeds when the plants were exposed to the HF treatment or were grown with lower levels of calcium, and the effects were additive. Continuous treatment with HF at 3 μg F per cubic meter had no apparent effect on tomato fruiting, even at the lowest level of calcium nutrition.

The practical significance of the effects of HF on plant fruiting is uncertain at this point since the minimum HF exposures at which effects on fruiting have been found are high in comparison to the levels of phytotoxic fluorides found in the ambient atmosphere, except possibly near some fluoride sources. The responses of additional plant species to lower HF concentrations will indicate the practical importance of these effects.

AIR POLLUTION EFFECTS ON PLANTS

Francis A. Wood
The Pennsylvania State University, University Park, Pennsylvania

Dr. Francis A. Wood, investigating the effect of air pollution on plants, has developed a fumigation chamber for exposing woody plants to various concentrations of ozone and peroxyacetyl nitrate (PAN) under precisely selected temperature, relative humidity, and light regime.

Dr. Wood developed the fumigation chamber by modifying a Model M2 Plant Growth Chamber manufactured by Environmental Growth Chambers, Chagrin Falls, Ohio.* Major modifications include treatment of interior surfaces to prevent corrosion by oxidants, use of Teflon insulation in internal wiring, installation of an air exchange system, and installation of a charcoal filtration system through which air is introduced. In this chamber, selected ozone concentrations can be maintained for indefinite periods with a maximum fluctuation of ±5 percent.

Using this chamber, Dr. Wood has exposed groups of 2- to 5-year-old seedlings of 22 tree species to 1, 25, and 50 pphm of ozone respectively for 8 hours at temperatures between 70° F and 75° F, relative humidities between 74 percent and 80 percent, and light intensities of approximately 1400 foot candles. White ash, Japanese larch, tulip poplar, jack pine, Austrian pine, pitch pine, eastern white pine, Virginia pine, eastern hemlock, and white oak showed acute symptoms after fumigation with 25 pphm. Symptoms on conifers included ivory flecking, chlorotic mottle, and tip neurosis. Hardwood leaves developed dark stipple on upper surfaces. Balsam fir, white fir, Norway spruce, white spruce, black hills spruce, blue spruce, red pine, Douglas fir, eastern white cedar, sugar maple, European birch, and linden were resistant to 25 pphm ozone.

Recent fumigation experiments indicate that jack pine is the most sensitive of the species, probably more sensitive than eastern white pine.

CYTOGENETIC EFFECTS OF HYDROGEN FLUORIDE ON CORN

Aly H. Mohamed
University of Missouri, Kansas City, Missouri

Since hydrogen fluoride (HF) is often a major gaseous component of atmospheric pollution, Dr. Aly H. Mohamed of the Department of Biology of the University of Missouri is investigating the cytological and genetic effects on plants of HF concentrations below those which produce detectable somatic damage. In his recent experiments, Dr. Mohamed used corn seeds of the genotype $A_1 A_2 C^1 R$ B Wx germinated in a greenhouse in polyethylene pots containing a horticultural soil mixture.

*Mention of a company or product does not constitute endorsement by the U. S. Department of Health, Education, and Welfare.

When the plants were about 2 feet high, eight plants were placed in a fumigation chamber and four plants were placed in a control chamber. Before experiments began, plants were left in the chambers for 2 days to adjust to conditions in the chambers. Temperature was maintained at 24° C, relative humidity was maintained at about 60 percent, and light was closely controlled for photoperiods of 14 hours. The concentration of fluoride gas in the fumigation chamber was kept close to 3 $\mu g/m^3$. In the 10 days during which the experiment was conducted, four sporocyte samples were taken; the first sample after 4 days and subsequent samples at 2-day intervals. Control runs were always made simultaneously with treatment runs.

The fumigated plants and the controls were moved back to the greenhouse after each treatment cycle. Pollen grains collected from each fumigated plant and those collected from the controls, were used to pollinate the recessive seed plants of stocks yg_2 C bz sh wx, a_2 bt pr, and a_1 A_2 sh_2 C R dt. All of the plants appeared healthy and showed no visible injury.

Meiotic analysis of microsporocytes of the treated plants showed the occurrence of heterozygous reciprocal translocations and inversions in the pachytene and bridges plus fragments in A_1. In a few cases the translocated chromosomes as well as the inverted ones were identified. These identifications are summarized below.

Type of aberration	Chromosome(s) involved	Breakage position
Translocation	1-2	1S.01, 2L.31
Translocation	5-10	5S.13, 10L.31
Inversion (pericentric)	1	L.18, S.21
Inversion (paracentric)	7	L.02, L.18

EFFECTS OF AIR POLLUTANTS ON PLANT GROWTH

A. Clyde Hill
University of Utah, Salt Lake City, Utah

Dr. A. Clyde Hill studied symptoms of ozone, PAN, and chlorine injury on a wide variety of crop and native plant species. Using several plant species and pollutant concentrations, he also studied the effectiveness of vegetation such as oats and alfalfa in removing ozone and nitrogen dioxide from the atmosphere. Resulting data indicate that vegetation might be an important sink for these gaseous pollutants. Wind velocity above the canopy, light intensity, extent of stomatal opening, and density of vegetation influence the pollutant uptake rate. The rate of pollutant uptake is related to plant injury as well as to atmospheric cleansing.

By comparing plant responses under sunlight, standard fluorescent light, and incandescent light, the investigator found that the source of light can affect response of plants to air pollutants. Wind velocity also influences the response of plants to pollutants.

PAN concentration of the ambient air was measured to determine the concentrations to which plants are exposed. PAN concentration in the ambient air is low in the early morning, builds up rapidly from 9:00 to 11:00 in the morning to a peak, then decreases to a relatively low level by mid-afternoon. When concentrations average 2 to 3 pphm for about 2 hours, many sensitive plant species develop injury.

After an extensive study of the effect of ozone on plant growth, investigators concluded that a high concentration of ozone causes a temporary reduction in the growth rate of most species. Measurements of stomatal openings have shown that ozone causes the stomata to close, reducing plant growth and transpiration rates.

The technician is selecting oat seedlings to investigate the effect of air pollutants, particularily peroxyacetyl nitrate and ozone on the mechanism of growth, specifically with respect to cell expansion in higher plant tissue. This work is conducted under grant AP 00213-06, entitled "Effect of Air Pollutants on Cell Growth," Dr. Lawrence Ordin, Principal Investigator.

AIR POLLUTION AND THE COMMUNITY IMAGE

Robert E. Rankin
West Virginia University, Morgantown, West Virginia

In a completed research project, Dr. Robert E. Rankin, of West Virginia University, investigated public attitudes and reactions to air pollution where it constitutes a significant and constant part of the environment. Dr. Rankin sought to determine (1) the public conception of air pollution and air pollution control, (2) the effect of air pollution on the public image of the community, and (3) attitudes and personal characteristics influencing individual conceptions of air pollution and its control. Investigators defined five separate population groups within the Kanawha Valley chemical-industrial area of West Virginia and scientifically selected samples for personal interviews. The samples included approximately 900 persons within the corporate limits of Charleston, 500 persons from three separate communities outside Charleston, and 800 graduating high school seniors from the Charleston area.

A significant majority in every community were both aware of and concerned about air pollution. In rating a number of typical urban problems according to seriousness, air pollution ranked first in all samples. Over three-fourths of the respondents in all communities except Charleston expressed some degree of dissatisfaction with air conditions. In Charleston almost half were dissatisfied. Over 90 percent of every population group agreed that air pollution existed in the community. Dust and dirt, chemicals in the air, and odors were most commonly associated with the term *air pollution*. From one-third to over three-fourths of the samples expressed some anxiety over the possible consequences of pollution.

Despite these significant expressions of concern at the community level, many people did not seem to feel personally affected by air pollution. In most areas people saw it as a much more serious problem in the community-at-large than in their own neighborhoods. Many appeared to consider pollution to be restricted to the area near the source that is around the plants. Most people seemed to feel personally affected only when they perceived pollution as a health threat.

Most people seemed to feel that air pollution could be greatly reduced, and even more favored action to reduce it. When questioned about what *would* be done, however, most people were pessimistic. Less than half of the respondents in all communities felt that there would be "noticeable improvement" in the next 5 years, while approximately 15 percent said that things would get worse. Knowledge about control programs already in progress was slight. Asked about efforts of Federal or regional agencies to deal with air pollution, two-thirds of those questioned were generally unaware of such action and less than 10 percent could give any substantive account of it.

From 14 to 43 percent of the respondents, depending upon the community, reported that they had felt, at times, like complaining about some aspect of air pollution, but in no community did more than 10 percent report that they had translated this feeling into action.

The interviews indicated that air pollution did have a significant effect on general community attitudes. Although satisfaction with living in the area did not vary much in relation to the perceived seriousness of pollution in the total community, people who saw serious pollution problems in their own neighborhoods did tend to be less satisfied. Spontaneous remarks early in the interviews (prior to any mention of pollution by the interviewer), indicated great awareness of air pollution in the region. Even though interviewees in Charleston seemed less aware than those elsewhere, nearly 60 percent of the Charleston sample brought up the subject on their own. When asked what single thing they would most like to change in their community, people ranked air pollution first everywhere except Charleston, where they ranked it second to the streets and traffic problem. Few people spontaneously mentioned pollution as a factor in changing their residences, but many (from 17 percent in Charleston to 47 percent in South Charleston) reported having seriously considered moving because of it.

The graduating seniors interviewed were significantly more concerned about air pollution than the general population. Twenty-two percent of those not wanting to remain in the Kanawha Valley gave air pollution as their most important reason, and 59 percent of the total high school sampled said that air pollution was the thing they disliked most about the region.

Investigators are continuing work on the third research objective, determinations of general personal characteristics influencing perception of air pollution and attitude toward the possibility of control. Thus far non-perceivers have tended to be more negative toward science, to have lower incomes and educational attainments, and to be older than perceivers. Those pessimistic about effective control were more anti-scientific, had lower incomes and educational levels, were younger, and were more alienated from societal norms than their more optimistic neighbors.

The relationship between the type and amount of pollution and the awareness of and concern about pollution has not yet been analyzed.

ANALYSES AND PHYSICOCHEMICAL INVESTIGATIONS

PHOTOCHEMISTRY OF SUBSTANCES PRESENT IN URBAN AIR

Harold Johnston
University of California, Berkeley, California

Dr. Harold Johnston has developed a new method of following intermediates, such as free radicals, in photochemical reactions. Utilizing long-path infrared absorption for direct observation of these free radical intermediates, Dr. Johnston will attempt to determine the mechanism of photochemical reactions which cannot be unambiguously determined by mere observation of reactants and products. With this approach, he anticipates important breakthroughs in unraveling what actually happens in complex photochemical systems, especially the photochemical oxidations that occur in air pollution. According to Dr. Johnston this method, which measures optical densities as low as 10^{-6} in an 80 meter path, is at least 100 times more sensitive than any other infrared method.

MECHANISMS OF PHOTOCHEMICAL REACTIONS IN URBAN AIR

J. N. Pitts, Jr.
University of California, Riverside, California

In his research into photochemical reactions in urban air, Dr. J. N. Pitts is investigating the reactions of excited (singlet) molecular oxygen with hydrocarbons as possible sources of pollutants in the atmosphere. Using singlet oxygen in the gas phases generated by microwave excitation of ground state molecular oxygen, Dr. Pitts found that the reaction of singlet oxygen with certain unsaturated hydrocarbons in a flow system produces high yields of selected stable peroxides. Singlet oxygen has been found to react with 2,5-dimethyl-2-methoxy-5-peroxyfuran. The similar reaction with 2,3-dimethyl-2-butene has produced only 2,3-dimethyl-3-peroxy-1-butene in better than 50 percent yield. Dr. Pitts and his associates are continuing their study of the reactions of singlet oxygen with hydrocarbons that have been identified in polluted atmospheres.

This group also is investigating the photochemistry of acrolein (CH_2=CHCHO) in the vapor phase. Acrolein is a constituent of photochemical smog and is stable toward photo-decomposition. The investigators believe, however, that unstable intermediates such as methyl ketene (CH_3CHCO), which might be formed during irradiation, may react readily with $0_2(^1\Delta g)$ in the atmosphere.

Initial research has dealt with the photochemistry of acrolein at pressures between 1 mm and approximately 50 mm. When that system is thoroughly understood, the investigations will be extended to include the range 10^{-4} mm to 10 mm, the atmospheric range. When these studies are completed, $0_2(^1\Delta g)$ will be introduced in both pressure ranges.

Dr. Pitts and his associates have developed a versatile chemical actinometer, suitable for field as well as laboratory studies, for the measurement of radiation intensities in the near ultraviolet range. The actinometer is a thin film of polymethyl methacrylate in which the actinic material, 0-nitrobenzaldehyde, is dispersed. Aborption of light in the 2800-4100A range causes 0-nitrobenzaldehyde to photoisomerise to 0-nitrobenzoic acid with a quantum efficiency of 0.50. The extent of this reaction upon irradiation can be related to the intensity of the radiation source. This actinometer is suitable for measuring solar radiation intensities within the region 3000-4100A, the photochemically reactive wavelength region for the production of photochemical smog.

SELENIUM AND ITS SIGNIFICANCE AS AN AIR POLLUTANT

Philip W. West
Louisiana State University, Baton Rouge, Louisiana

Dr. Philip West is conducting two research projects, "Separation and Estimation of Airborne Particles" and "Atomic Absorption Spectroscopy of Trace Poilutants." One important result of Dr. West's research is the discovery of selenium in papers and in the effluents from trash burning operations and incinerator stacks. His research group also has contributed numerous techniques for separation, identification, and estimation of various airborne particulates and has developed atomic absorption spectroscopy for application to air pollution and related studies.

Selenium, which may be associated with lung cancer, emphysema, and cardiovascular defects among cigarette smokers, has been found in paper made from flax straw (cigarette paper) as well as papers made from wood pulp. Researchers have developed three different methods for determining minute traces of selenium. They also are investigating the presence of selenium in tobaccos and in air, particularly in the atmosphere around trash burning operations and municipal and apartment incinerators.

The research team is investigating methods for the study of airborne particulates in order to develop methods that are highly sensitive, selective, and reliable. The investigators have concentrated on the development of ring-oven methods for the highly specialized requirements of air pollution studies. According to Dr. West, the ring oven itself can be shop constructed or can be purchased for less than $200. The ring-oven methods require no special training, and the procedures are generally rapid, reliable, and accurate. These methods are versatile and are applicable to the study of complex mixtures. They can determine pollutants in parts-per-million and parts-per-billion concentrations.

Dr. West's team has developed reagent crayons for convenient and simple field detection of pollutants. Selected reagents dissolved in a low melting matrix are poured into small tubes such as drinking straws. Upon cooling, the solutions solidify to form stable mixtures, like ordinary marking crayons, that provide distinctive colors when streaked across test surfaces on which pollutants are absorbed.

An important part of the research program has been the development of trace analysis methods. Atomic absorption spectroscopy holds great promise because it is inherently specific and is extremely sensitive. Methods have been developed which can determine pollutants in parts-per-million and parts-per-billion concentration ranges.

MECHANISMS OF PHOTOCHEMICALLY INITIATED OXIDATIONS

Jack G. Calvert
Ohio State University, Columbus, Ohio

Dr. Jack G. Calvert is attempting to determine the complex mechanisms by which chemical reactions occur in the polluted atmosphere, especially in the polluted atmosphere irradiated by sunlight. He is investigating the reactions of a variety of light absorbing compounds known to be present in the polluted atmosphere. In studying the photochemistry of several components of known importance in polluted atmospheres, Dr. Calvert is employing a variety of quantitative physical methods, including flash photolysis, long-path infrared spectroscopy, visible and ultraviolet spectroscopy, emission studies, and electron spin resonance spectroscopy.

Extensive study of formaldehyde, the simplest of the carbonyl compounds, has yielded quantitative data delineating the nature and extent of the primary processes in the photolysis of this compound. These data should be particularly useful in the calculation of rates of CH_2O photooxidation and H and HCO formation in sunlight-irradiated polluted atmospheres. Efforts to establish what happens to the H and HCO in the atmosphere continue.

Dr. Calvert has determined the relationship between structure and photodecomposition modes in a variety of related ketones. He is studying the photochemistry of the sulfur dioxide molecule and of its photosensitized oxidation in the presence of organic peroxy radicals. The reaction mechanisms of the organic fragments (free radicals) formed in an oxygen rich media have been determined for a variety of systems. Investigators have studied the methyl, acetyl, ethyl, propyl, tert-butyl, and n-butyl radicals, and have determined probable mechanisms of their reactions in the absence and presence of oxygen and nitric oxide.

Dr. Calvert and his associates are continuing their study on the mechanisms and intermediates involved in the photochemical oxidations sensitized at the surface of metallic oxides and sulfides. They intend to evaluate the importance of various inorganic particulates in the chemical dynamics of the irradiated polluted atmosphere.

BIOENGINEERING ASPECTS OF AIR POLLUTION
Sheldon K. Friedlander
California Institute of Technology, Pasadena, California

Much of Dr. Sheldon K. Friedlander's research is concerned with the size distribution (the number of particles of any given size) of the fine particles present in fumes, smokes, and smog. Since particle size is related to particle deposition in the human lung, such studies may yield important results. In addition, the designing of gas cleaning equipment such as filters and electrical precipitators requires reliable information on particle size distribution.

As a result of their dancing motion, due to molecular bombardment, particles in a smoke or fume collide and stick together, steadily increasing the number of larger particles and decreasing the number of smaller ones. Dr. Friedlander and his associates have discovered that this process leads to definite particle size distribution, and they have worked out a mathematical theory that predicts the number of particles of each size. This theory enables one to determine from only a few measurements the size distribution of a fume or smoke, and thus to save considerable time and money.

BEHAVIOR OF AEROSOL PARTICLES
Robert S. Sholtes
University of Florida, Gainesville, Florida

By observing aerosol particles through an image intensifying apparatus, Dr. Robert Sholtes is able to observe their behavior via scattered light without limitation of light intensity and rapidity of particle movement. The apparatus has been successfully assembled and its performance demonstrated.

With a dust counter installed in a light aircraft, Dr. Sholtes has experimented with the use of particle count to trace a plume in the downwind direction. The source of the plume was a power plant burning pulverized coal without any particulate controls. Since it was in an isolated area on the Gulf coast of Florida, there were no interfering sources, and dispersion patterns could be examined over both land and sea areas. Dr. Sholtes traced the plume for 40 miles downwind and established plume aerosol concentrations in both horizontal and vertical axes.

CONTROLLED SOURCE OF UNIFORM LIQUID DROPLETS
Charles D. Hendricks
University of Illinois, Urbana, Illinois

Much air pollution research calls for reliable, controlled sources of uniform small particles, to serve as models of polluting materials and as calibration sources. Professor Charles D. Hendricks is attempting to

develop such sources to deliver particles with diameters in the micron range and with size distributions of 10^{-2} or less standard deviation. Professor Hendricks is also investigating particle-particle and particle-surface interactions, and the ease with which he is able to control particle size and electric charge has led to studies of charged particle behavior.

Since control and dissipation of various types of air pollution require a knowledge of the behavior of liquid drops upon collision with other drops or with solid particles, this project particularly has been concerned with collision and coalescence. The behavior of colliding droplets is an important consideration in the design of systems to remove or control pollution from industrial sources.

A droplet generator developed in Professor Hendricks' laboratory affords excellent control of size and charge and can produce uniform droplets down to a few microns in radius. Significant characteristics of this droplet generator are:

1. The low pressures required to form liquid jets through narrow capillary openings
2. The low power necessary to drive the quartz crystal, electromechanical transducers coupled to the liquid jets to disrupt them into droplets
3. The high-speed electronic-pulse techniques employed for light synchronization with the droplet stream and for separation of individual droplets for collision experiments

A multiple-stream droplet generator is being constructed to produce large quantities of micron-size droplets.

Professor Hendricks and his associates also are studying an emission process requiring only the collision of a small droplet and a large drop with an electric field at the surface. This electric field may be produced by a charge on the drop, which is below the Rayleigh limit, or by the presence of an external electric field. If a small uncharged droplet is collected by a large, charged drop, the droplet touches the surface of the drop and remains there for a short time (the coalescence delay time) then begins to coalesce into the drop. If the electric field at the drop surface is high enough, the droplet coalesces, but a new, highly charged droplet is emitted because of instability due to the electric stress on the surface. Investigators have verified the essential elements of this process analytically and experimentally.

Although research so far has produced relatively large particles, it is being extended to the smaller sizes (a few microns or less). In preliminary investigations, ice particles were formed by freezing of water droplets and lucite particles by evaporation of a solvent. Investigators concentrated, however, on production of sodium nitrite particles by freezing of molten droplets because of the ease of working with this material. This process yielded uniform particles less than 200 microns in diameter with more than 10^4 coul/kg specific charge at a rate of 11,000 per second. The techniques developed in this work are being extended to small particle production.

FORMATION AND DECAY OF ATMOSPHERIC AEROSOLS

Alexander Goetz
Atmospheric Research Group, Altadena, California

Dr. Alexander Goetz, of the Atmospheric Research Group, Altadena, California, is studying aerocolloid formations of reactive hydrocarbons in the biosphere as part of his research into formation and decay of atmospheric aerosols.

Investigators have revealed that, depending on time and location, the number and size of the particulates in the ambient air can be considerably enlarged, often by an order of magnitude, when the sampled air flow, prior to precipitation of the aerosols, is briefly ($\leq$45 sec.) exposed to UV-irradiation at 2537 A. The precipitated particulates are very sensitive to subsequent thermal or UV-exposure for extended duration ($>$30 min.).

This transformation of molecular-dispersed hydrocarbons into small particulates irradiation appar-

ently involves photochemical oxypolymerization and subsequent coagulation. The particles, apparently mostly liquid and highly hydrophylic, appear to be active centers for H_2O-condensation.

Dr. Goetz's findings offer a rapid and simple method for determination of the presence and quantity of potentially reactive hydrocarbon traces in terms of their capacity to polymerize into particulates, and for discrimination between these traces and the aerocolloid matter that already has reacted under sunlight irradiation.

COMPOSITION OF LEAD HALIDE POLLUTION AEROSOLS

John W. Winchester
University of Michigan, Ann Arbor, Michigan

Professor J. W. Winchester and Dr. W. R. Matson of the Department of Meteorology and Oceanography, University of Michigan, have constructed a multiple anodic-stripping device that can perform up to 20 analyses per hour for nanogram quantities of lead, copper, cadmium, and bismuth in natural and pollution aerosols. These investigators have found that under certain conditions, between 10 percent and 80 percent of the lead found in 1- to 10-micron-radius particles in aerosols and in natural waters is bound to the particles and is released very slowly, half times of dissociation varying from 10 to 100 minutes. The binding of trace metals to atmospheric particles may be a factor in the body's uptake of these materials through the lungs and moist tissues.

Professor Winchester and Dr. Matson are using a combination of anodic-stripping lead determination and neutron activation analysis of the elements chlorine, bromine, and iodine to study the composition of lead halide pollution aerosols. Particles have been fractionated over the radius range 0.25 to 8 microns. Preliminary studies of urban aerosols in Ann Arbor indicated that chlorine is enriched in the largest particles, bromine is enriched in the smallest, and iodine is variable. Some of the lead samplings show a pronounced maximum near 1 micron. These results are consistent with the hypothesis that bromine is condensed onto the surfaces of the small particles in the gas phase, whereas chlorine is associated primarily with the large particles. If pollution iodine were added to the atmosphere mainly in an oxidized state, it would not be rendered volatile by reaction with oxidants as are pollution bromide and natural iodine in sea water. Enrichment of pollution iodine in the smallest particles, therefore, is not expected.

INFLUENCE OF AEROSOL CHARACTERISTICS ON VISIBILITY

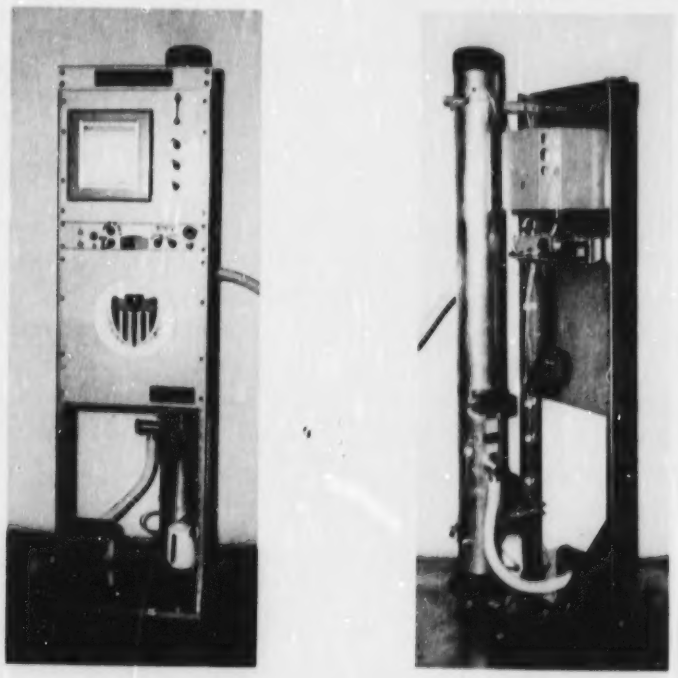
R. J. Charlson
University of Washington, Seattle, Washington

Decreased visual range, one of the most obvious effects of air pollution, is the result of light scattering caused by very small particles suspended in the atmosphere. In a research project directed initially by Professor A. T. Rossano and more recently by Dr. R. J. Charlson, investigators at the University of Washington, at Seattle, have discovered a relationship between the amount of particulate matter suspended in the air and the visual range.

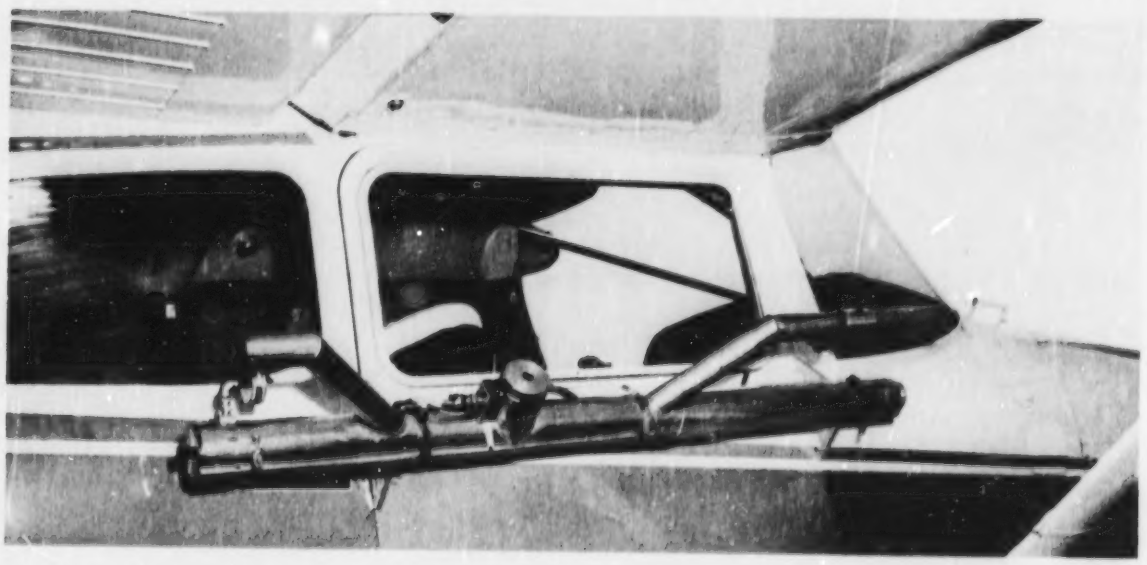
Determination of this relationship was made possible largely by the development of an instrument for measurement of the pertinent optical factor. This instrument, called an integrating nephelometer, already has been used in pollution monitoring as well as in research. One instrument built by the University of Washington group has been used by the Puget Sound Air Pollution Control Agency for monitoring the visibility degradation at the site of the 1962 Seattle World's Fair.

Perhaps the most important application of a relationship between the amount of particulate pollutant and the visual range is in the area of air quality standards. Results of this project indicate, for instance, that maintenance of the 5 km (3 mile) visual range for aircraft operations under Visual Flight Rules, would

require that particulate matter be kept at less than about 240 micrograms per cubic meter of air. Although the amount does vary, 90 percent of all cases for a 5 km visual range should fall between 120 and 480 micrograms per cubic meter. Dr. Charlson has tested this result in extensive field experiments in New York City, in San Jose, and in Seattle. Similar results were obtained by an entirely different method by the California Department of Public Health.



The integrating nephelometer developed by R. J. Charlson under a research grant to the University of Washington.



Integrating nephelometer mounted on aircraft.

PRIMARY PRODUCTS OF PHOTODISSOCIATION

Dr. Kent R. Wilson
University of California (San Diego), La Jolla, California

Photodissociation, the breakup of molecules under the influence of light, is a basic process in photochemical air pollution. The absorption of light energy and the production of molecular fragments initiate complex chains of atmospheric chemical reactions leading to smog. Although photodissociation has been extensively studied, the details of the process, on a molecular level, have been difficult to determine.

Dr. Kent R. Wilson and his associates have developed a new procedure, photodissociation translational spectroscopy. They cross a beam of molecules and a pulse of laser light inside a vacuum chamber to cause some of the molecules to dissociate. By measuring the flight times of the fragments over a several-centimeter path to a mass spectrometer, the investigators determine their velocities, or translational energies. The new procedure is being used in two studies.

First, the research group is attempting to learn the details of the photodissociation of NO_2, a basic process in smog production. They already have made preliminary measurements of the partitioning between translational energy and internal energy of the fragments in order to determine the electronic states involved in the dissociation.

The second study is to determine the masses of the fragments of molecules, such as nitrates, aldehydes, and ketones, whose photodissociation is important in air pollution. With their new procedure, the investigators can measure the fragments directly, before they strike other molecules or walls.

Translational spectrometer used in studying the photodissociation of nitrogen dioxide. The equipment has been developed by Dr. Kent R. Wilson under a research grant to the University of California.

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DEVELOPMENT OF ANALYTIC METHODS AND EQUIPMENT

GENERATION AND DECAY OF SMALL IONS

A. R. McFarland
University of Minnesota, Minneapolis, Minnesota

The initial objectives of the research directed by Dr. A. R. McFarland of the University of Minnesota, were to study generation of small ions with a new sonic-jet ion generator, to study physics of decay of high ion concentrations in flowing jets and in the presence of aerosols, and to develop systems for neutralizing of electrostatic charge on particles. Significant products of these studies include a sonic-jet ion generator which, when used to generate bipolar ion atmospheres, is also an effective aerosol neutralizer and a practical electrical-particle counter for the submicron range.

The sonic jet ion generator has been widely used as a research tool for ion generation, for charge neutralization, and for other purposes. It is an essential part of several aerosol generators used for calibration of aerosol-measuring instruments.

The electrical particle counter is the first practical *in situ* particle counter for the 0.01- to 1-micron range. In combination with a condensation nuclei counter and an optical counter, it constitutes the first automatic system for measuring aerosol size distribution over the complete range of sizes normally found in the atmosphere.

Dr. McFarland and his associates have also developed other charged-particle-measuring techniques and devices, including a new electrostatic aerosol sampler capable of highly accurate sampling of aerosols on electron-microscope grids and light-microscope slides simultaneously.

PARTICULATE SAMPLING BY ADHESIVE-COATED MATERIAL

Charles Gruber
City of Cincinnati, Cincinnati, Ohio

Having successfully used adhesive-coated paper wrapped around circular glass jars for monitoring windblown particles, the Cincinnati Division of Air Pollution Control wished to employ this device in wide-scale air pollution studies. Charles Gruber's project comprised the evaluation of this device and the establishment of criteria for its use.

Mr. Gruber has determined the best materials for the collectors and has investigated the factors affecting particle collection. Cylinder diameter, wind speed, total miles of wind, and precipitation are important factors affecting particle collection, while electrostatic forces are of little or no importance. Total particle loading on the adhesive sampler used in atmospheric surveys varies from 8 to 20 percent, depending upon the location of the sampler.

Using a laboratory wind tunnel designed for this project, Mr. Gruber found the actual and the theoretical impingement efficiencies of the adhesive sampler to be closely correlated. He calculated the collection efficiency of the sampler to be 24 percent at 5 mph, 37 percent at 10 mph, and 54 percent at 15 mph.

Of the particles collected on the adhesive, 85 percent were greater than 11 microns in diameter, 60 percent were greater than 22 microns, and 30 percent were 22 microns to 44 microns in diameter.

A recommended standard method for measuring windblown nuisance particles has been drafted, and field application of the method is in progress to verify its effectiveness.

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POLLUTION ABATEMENT BY PROCESS GAS CHROMATOGRAPHY

Michael Schaer
Montana State University, Bozeman, Montana

Dr. Michael Schaer, at Montana State University, has developed a process gas chromatograph using a bromine microcoulometer detector sensitive to 1-ppm quantities of various sulfur compounds, such as H_2S, SO_2, and CH_3SH. Lately, he has been attempting to solve two problems with the detector, noise and deterioration of the electrolyte solution. Improvements in cell design have partially solved the noise problem, and improvements in electrode design may further reduce the noise. Problems arising from deterioration of the electrolyte have been solved by the addition of a new electrolyte every 10 hours.

Since the ordinary strip chart output from a process gas chromatograph is not adequate in a modern day paper mill, Dr. Schaer is equipping the chromatograph to provide digital display of the concentrations of the various sulfurous gases. A standard teletype printer will provide the digital display. In addition, a paper tape which can be processed on a digital computer will be punched. The tape will allow rapid determination of the relationship between plant operation and total sulfurous gas emission. This information will provide management with a clear basis for corrective action to minimize air pollution.

STUDY OF ATOMIZER AEROSOL GENERATORS

K. T. Whitby
University of Minnesota, Minneapolis, Minnesota

Dr. K. T. Whitby, of the University of Minnesota, is attempting to develop a set of monodisperse-aerosol generators that can be used for aerosol research, air cleaner testing, and calibration of aerosol sampling and measuring instruments.

Some of the generators being studied in this project are:

1. An improved atomizer-impactor aerosol generator for polystyrene latex in the 0.01μ to 0.5μ range
2. An improved condensation aerosol generator for aerosols in the 0.03μ to 1.3μ range
3. An improved spinning disk generator
4. Hollow-cone atomizers for monodisperse aerosol in the 1μ to 30μ range

In addition, preliminary experiments with specially prepared freon solutions of DOP in aerosol cans suggest that they might be used to generate moderately monodisperse DOP aerosols of reproducible size.

Dr. Whitby also has been studying electric-charge distribution and residue-particle-size distribution, on polystyrene latex (PSL) aerosols.

He has measured the relatively high electric charges on 0.8μ PSL. Since removal of this high charge is necessary for certain uses of the aerosol, the new PSL generator incorporates a Krypton 85 charge neutralizer.

The investigator also found that 10^3 to 10^4 residue particles are generated for every PSL particle. These residue particles are a significant source of spurious pulses in the calibration of optical counters.

STUDY OF ODOR COMPONENTS OF INDUSTRIAL EXHAUST

Norman M. Trieff
Drexel Institute of Technology, Philadelphia, Pennsylvania

One of the primary objects of Dr. Norman M. Trieff's investigations was to develop effective methods of sampling and analysis of industrial odors and to analyze emissions from rendering plants in the Philadelphia area. Several sampling approaches have been successfully employed.

In the first method, air was pumped from within or immediately outside the rendering plant through a K_2CO_3 drying tube and onto a U-tube. The U-tube was packed with glass beads or chromosorb W coated with apiezon L and immersed in liquid N_2. After sampling, the U-tube was attached to a chromatographic column in the chromatograph oven. The U-tube served as a precolumn and released the sample without appreciable fractionation. Over 20 components were separated and detected in the chromatogram. Reproducibility was good, but component size was too small to be easily identified.

In the second method, a larger sample was obtained by adsorption of odors on charcoal; heating of the charcoal in a vacuum oven; and drawing of the odorous vapors through a drying tube onto a packed U-tube, cooled in liquid N_2, which served as a precolumn for the gas chromatograph.

Dr. Trieff is now attempting to identify components through retention times from G.L.C., I.R. spectra, and mass spectra.

ACTIVATION ANALYSIS OF ATMOSPHERIC PARTICULATES

Roy G. Post
University of Arizona, Tucson, Arizona

Dr. Roy G. Post has employed neutron activation analysis for routine, rapid analysis of the elemental composition of particulates obtained from air sampling stations. In Dr. Post's technique, a computer program automatically performs both qualitative and quantitative analyses.

Only one sample spectrum is necessary for the qualitative analysis since this analysis is based only on gamma-ray peak energies, not on half-life, To perform quantitative analysis, this technique utilizes a permanent isotopic spectra library stored on magnetic tape for matrix unscrambling of the composite spectrum. Because the unscrambling scheme minimizes the amount of computer storage required, a 1024 channel spectrum containing 20 components can be analyzed using only about 800 words of core storage.

In this method, the sample is assumed to have unknown composition but a limited number of possible constituents. Program input consists of raw data from the spectrometer under a variety of experimental conditions. The output consists of both the isotopic and elemental sample composition in micrograms. Errors in the spectrum unscrambling are only a few percent for the most abundant constituents.

PORTABLE SPECTROMETRIC ANALYZER FOR AIR POLLUTANTS

David T. Williams
University of Florida, Gainesville, Florida

The effective study of air pollution demands rapid and effective measurement of pollutant concentrations. Molecular correlation spectroscopy, a new method developed by Dr. David T. Williams at the University of Florida College of Engineering, measures these concentrations accurately, rapidly, and conveniently.

This method allows field measurement of concentrations of a few parts per billion of SO_2, NO_2, NO, NH_3, C_6H_6, $C_6H_5CH_3$, and other pollutants, over path lengths of approximately 100 meters. Other materials in the air do not interfere with these quantitative measurements. Molecular correlation spectroscopy can be used to measure any gaseous chemical having a band or line spectrum, either visible or ultraviolet. In the field of air pollution, it can be used for hitherto impossible quantitative studies of atmospheric interactions.

METEOROLOGY

TRAVELS OF AIRBORNE POLLEN

Eugene C. Ogden
The University of The State of New York, Albany, New York

Although pollen is a major air pollutant and an important cause of respiratory disease, little has been known about pollen dispersion and the factors that influence pollen concentrations. Dr. Eugene C. Ogden, State Botanist of New York, is directing research to add to the knowledge of these things. The basic accomplishments of this research include:

1. Development and evaluation of samplers for airborne particles of pollen size
2. Development of techniques for tagging pollen in living plants with radioisotopes and with dyes for artificial simultaneous dispersion from multiple point sources
3. Determination of the influences of pollen properties, source characteristics, meteorological conditions, surrounding terrain, and vegetative cover upon dispersion and deposition patterns of ragweed, timothy, and corn pollen from known sources over open terrain
4. Accumulation of data on the effects of forested areas in removing pollen from the air and comparison of removal rates in forests to those in non-forested areas
5. Determination of the effects of height, time, source location, terrain, vegetation, and weather upon concentrations of naturally produced pollen
6. Preparation for development and testing of mathematical models to predict dispersion and deposition from single and multiple pollen sources

The project has added to knowledge of the mechanisms of pollen dispersion and has facilitated adequate assessment of the variables that influence dispersion.

The data acquired in this project may be helpful in the evaluation of proposed weed-control programs. Since pollen sources are, in many ways, representative of area sources of airborne pollutants, results of this research into pollen dispersion also should be useful in the study of other air pollution problems.

VISIBLE SPECIES OF ALGAE AND PROTOZOA IN THE ATMOSPHERE

H. E. Schlichting, Jr.
North Texas State University, Deaton, Texas

Dr. H. E. Schlicting, Jr., of North Texas State University, has studied the numbers and species of algae and protozoa in the atmosphere and has conducted investigations in Michigan, North Carolina, and Texas. Using filters and bubblers containing soil-water extract, investigators collected samples throughout the year under environmental conditions including freezing rain, heavy snow, fog, and summer temperatures up to 39.4°C and at heights ranging from 6 to 7,500 feet.

To ensure uniform and valid results and to reduce the possibility of damage to the collecting medium or to the collected organisms, short sampling periods (1-2 hours) and a slow rate of sampling, usually less than 1 cubic foot per minute, were employed. Better correlations were made of the quality and quantity of algae in the air with vertical updrafts than with wind velocity or direction which often showed little or no correlation with the aerial biota.

Preliminary investigations revealed that the aerial biota does include viable species of algae. Some of the species identified are known to be toxic and to invade water supplies. Additional studies should provide needed information on the survival and dispersal of these organisms in the atmosphere.

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ATMOSPHERIC DIFFUSION IN THE INERTIAL SUBRANGE

Paul MacReady, Jr.
Meteorology Research, Inc., Altadena, California

In the first phase of a study of fundamental relationships between turbulence and diffusion, Dr. Paul MacCready, Jr., has investigated discrete particle tracer techniques that would approximate the motions of neutral fluid particles. Dr. MacCready found that a small, helium-filled balloon with negligible superpressure and zero net lift is an ideal tracer of turbulent motions down to scale lengths comparable to the balloon's diameter. The balloons used were opaque, white, rubber balloons approximately 25 cm in diameter when inflated. The effects of radiant heating on the balloon's buoyancy were found to be generally negligible.

Elsinore Valley and El Mirage Dry Lake in California were chosen as sites for the balloon experiments because of their smooth and uniform fetches and their constant wind directions. The tracking system consisted of a synchronized pair of phototheodolites oriented crosswind on a 303-meter baseline. The balloon tracers were carefully neutralized in a closed van, carried aloft by a free-lift balloon, and released at a preselected height by a passive mechanism as either point source clusters or clusters with finite inertial separations in the crosswind and vertical directions. During the tracking of the balloon clusters, an instrumented aircraft made along-wind and crosswind traverses in the vicinity of the balloons to measure the turbulence dissipation rate and, in the later experiments, to provide complete two-dimensional energy spectra.

The balloon data are to be reduced and categorized on the basis of turbulence and meteorological conditions. Information gained from this analysis should facilitate meaningful comparisons between observations and theoretical predictions.

Dr. MacCready also developed a method for the use of soap bubbles as a tracer technique. In these investigations, he developed a technique for generating permanent, buoyant soap bubbles and a method for photographing the bubbles at considerable distances in the dark.

MESOSCALE WIND SYSTEM AROUND THE GREAT LAKES

E. Wendell Hewson
University of Michigan, Ann Arbor, Michigan

Because of the great role that shoreline wind systems play in the transport of pollutants in the industrialized Great Lakes area, knowledge of these systems is vital for control of pollution from lakeside industries. Research under the direction of Dr. E. Wendell Hewson, at the University of Michigan, has provided new information about these wind systems.

Using triangulation methods to track both freely rising and neutral balloons, investigators have learned that during the late spring and summer, the local wind from the lake to and over the land, known as the lake breeze, often commences about 11 a.m. and extends upward from the surface ½ to 1 km. As it advances over the land, the cool lake air often has a clearly defined leading edge, known as the lake breeze front. The cool air may advance in several steps: it may initially advance from 5 to 10 km inland, then remain almost stationary for as many as 3 hours, and then move rapidly inland for distances up to 20 km.

Aloft, from ½ to 2 km, there is often a return current with lighter winds than the lake breeze. Dr. Hewson suggests that such pronounced return currents aloft occur more frequently near the lakes than near middle-latitude sea and ocean shorelines, presumably because the circumscribed area of a lake constrains the air flow. Neutral-balloon tracking in and near Chicago has revealed looping patterns of air flow, with similar pronounced patterns of smoke behavior, under low regional wind conditions.

Increased knowledge of these local winds should facilitate analysis of the transport of air pollutants emitted by the rapidly growing industrial megalopolis south of the Great Lakes.

INVESTIGATION OF ICE FOG PROBLEMS

Takeshi Ohtake
University of Alaska, College, Alaska

Dr. Takeshi Ohtake, of the University of Alaska, has investigated ice fog, a kind of "low-temperature air pollution," in the Fairbanks, Alaska area. Ice fog is produced by the rapid cooling of saturated warm water vapor injected into a very cold atmosphere, -30° F or below, already near ice saturation. In subarctic populated areas, such as Fairbanks, this phenomenon presents problems in transportation and in health.

The three primary sources of ice fog are open water, automobile exhaust, and heating plant exhaust. In the formation of ice fog, water vapor first condenses to form small liquid droplets. As these droplets diffuse away from the source, rapid cooling causes many of them to freeze. As further diffusion occurs, the remaining droplets evaporate, forming and adding to ice particles by sublimation and maintaining the atmosphere near ice saturation.

Dr. Ohtake has investigated the sources of water vapor and its role in formation of ice fog, the relationship between concentration of ice fog particles and concentrations of ice nuclei and condensation nuclei, and, using an electron microscope, characteristics of nuclei and crystals.

Dense ice fog was found to be associated with large sources of moisture regardless of the number of nuclei. The total concentration of ice fog particles increases as the ambient temperature decreases: the concentration ranges from about 125 particles per cubic centimeter at -35° C to about 225 per cubic centimeter at -42° C. The most common diameter decreases with the ambient temperature, from about 12 microns at -36° C to about 3 or 4 microns at temperatures below -40° C.

Dr. Ohtake also measured the temperature profile over open water, one of the major sources of ice fog, under various air-temperature conditions. Although the water temperature was near 0° C, the air temperature as low as 2 meters above the water surface was the same as the ambient temperature. At 5 centimeters above the surface, air temperatures were only a few degrees higher than ambient temperatures as low as -40° C. Because of this very strong temperature gradient near the open water surface, many supercooled water droplets can be expected to condense from the water vapor above the open water and to be frozen very quickly. Auto exhaust vapors emitted into very cold air act similarly.

Further investigation on the measurements of ice nuclei, the freezing of water droplets, the electrical properties of ice fog particles, and the relationship between ice fog and water vapor are continuing.

DESCRIPTION AND CONTROL OF AIR POLLUTION SOURCES

FORMATION OF OXIDES OF NITROGEN DURING COMBUSTION

B. H. Sage
California Institute of Technology, Pasedena, California

Dr. B. H. Sage has completed investigations on the effects of oscillatory combustion on the formation of residual partial oxidation products. An atmospheric combustor, approximately 13 feet long and 4 inches in inside diameter, and a pressure combustor, approximately 2 feet long and 1 inch in inside diameter, were used in this research. Each combustor consisted of a water-cooled copper tube with side ports for measurement of perturbations in normal stress and in monochromatic and total optical intensity.

Investigators experimented primarily with flames produced by premixed air and natural gas in varying ratios, although they did conduct limited experiments in the pressure combustor with mixtures of air and methane, ethane, propane, and n-butane. They insured close approximation of macroscopic steady state since the nature of the perturbations encountered in oscillatory combustion are markedly influenced by minor changes in experimental conditions.

Early experiments revealed that oscillatory combustion increases residual oxide by as much as fiftyfold and usually by at least thirtyfold. The increase in the oxides of nitrogen as a result of unstable combustion underscores the importance of sufficient attenuating devices to avoid oscillatory combustion in atmospheric combustors. Baffles and checkerbrick are effective and practical attenuating devices.

Studies of the perturbations in monochromatic intensity which occur at the same frequency as the perturbations in normal stress indicate distinct perturbation in the mole fraction of both water and carbon dioxide which may supply the energy necessary to maintain the oscillations. Over the wide range of conditions under which the combustion of air and natural gas was investigated, the frequency of the perturbation varies between 500 and 900 cylces per second. The waves are substantially sonic, although the perturbations in normal stress deviate markedly from the conventional sign wave often ascribed to acoustic phenomena. In the atmospheric combustor the frequency varies from approximately 700 cycles per second below stoichiometric to approximately 900 cycles per second above the stoichiometric mixture ratio, and approximately six nodes are encountered at different longitudinal positions within the combustor.

The direct support of primary perturbations at frequencies in excess of 900 cycles per second appears difficult to obtain at relatively low pressure. A tangential traveling wave, however, is often encountered in both combustors.

In summary, the residual quantities of oxides of nitrogen are increased many times by oscillatory combustion. Such perturbations in normal stress and in monochromatic and total intensity apparently are associated with perturbations in the principal reactions connected with combustion of natural gas and air.

REDUCTION OF POLYCYCLIC AROMATIC HYDROCARBONS

Ronald Long
University of Birmingham, Birmingham, England

In his study of the formation of polycyclic aromatic hydrocarbons (p.c.a.h.), Dr. Ronald Long has developed a relatively rapid method of identifying and measuring these hydrocarbons in soot samples. The samples are extracted in chloroform, and the soluble material is then chromatographed on a column of silica gel with benzene as eluent. The individual p.c.a.h.'s in the benzene eluate then are determined by

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programmed-temperature gas chromatography using dual flame ionization detectors. Peaks in the gas chromatogram are identified by comparison of the relative retention times with those of pure p.c.a.h. and by ultraviolet absorption spectrophotometry of the fractions separated by gas chromatography.

Dr. Long has determined the amounts of chloroform-soluble material, polycyclic aromatic hydrocarbons, and carbonaceous residue in the dry soot recovered from an ethylene-diffusion flame and has investigated the effects on these materials of changes in the oxygen index of oxygen-nitrogen and oxygen-argon mixtures supplied to the flame.

In the case of oxygen-nitrogen mixtures, the amounts of chloroform-soluble material and of polycyclic aromatic hydrocarbons decrease rapidly as the oxygen index increases from 0.18 to 0.26. The amount of dry soot reaches a maximum at an oxygen index of about 0.26; above this value, it decreases rapidly in amount and is composed almost entirely of carbonaceous material.

Substitution of argon for nitrogen leads to higher temperatures in the reaction and pyrolysis zones. At lower oxygen indices, these higher temperatures favor the formation of carbonaceous residue and reduce the amount of polycyclic aromatic hydrocarbons in the soot. At higher oxygen indices, the amounts of soot (actually carbonaceous residue) are reduced.

These results emphasize the undesirability of either a general or local depletion of oxygen in the diffusion-flame combustion of hydrocarbons since such a depletion increases the formation of polycyclic aromatic hydrocarbons, including the carcinogen 3:4-benzopyrene. Oxygen enrichment of combustion air can greatly reduce the concentration of p.c.a.h. in the soot. If sufficient oxygen is added to the fuel itself, p.c.a.h. can be eliminated from the soot.

This research group also has studied diffusion flames of ethylene and of propane burning in air and the effects of hydrogen, acetylene, and oxygen as additives. The sooting rates of the flames both of ethylene and of propane increase with the addition of acetylene, and decrease slightly with the addition of hydrogen. The addition of oxygen increases the sooting rate of the ethylene flame but decreases that of the propane flame.

PARTICULATE EMISSIONS FROM WOOD WASTE

Richard Boubel
Oregon State University, Corvallis, Oregon

In a study of particulate emissions from wood waste combustion, Dr. Richard W. Boubel, of Oregon State University, has developed a rugged and reliable portable sampling train that enables a field crew to obtain a particulate sample from the top of a 50- to 60-foot wigwam-type burner in approximately 1 hour. Using this sampling train, investigators obtained several samples of particulates from representative sawmill burners. The nature of the emissions from these burners was determined be means of microscopic and gravimetric analyses.

Size distribution and mass rate of emission were found to vary greatly with combustion conditions within the burners. These two factors, size distribution and mass rate of emission, greatly affect transport properties, soiling properties, and visibility reduction, which in turn affect public reaction. Because of the great number of burners (500 in Oregon alone) and the wide variation in operating conditions, broad categories probably will be necessary for cataloging the emissions from the wigwam burners.

Standardized tests were run on many of the types and forms of fuel used in wigwam burners, and the results of proximate analyses were cataloged. This information should be valuable in research on combustion characteristics of wood fuels.

CARBURETORS – REDUCTION OF ENGINE EXHAUST EMISSIONS

Jay A. Bolt
University of Michigan, Ann Arbor, Michigan

Professor Jay A. Bolt, of the University of Michigan, has investigated factors affecting the fuel/air mixture ratio in automobile carburetors. The fuel/air mixture ratio supplied to the engine by the carburetor is the most important factor affecting the quantity of undersirable exhaust emissions from gasoline engines. A leaner mixture (high in air) produces less undesirable unburned hydrocarbons and carbon monoxide. The accurate control of this ratio by the carburetor is, therefore, very important in the control of air pollution.

Professor Bolt's tests revealed that carburetor enrichment is quite close to that predicted by theory, that is, the fuel/air mixture ratio varies in inverse proportion to the square root of the air density. Altitude, however, does affect this performance. Automotive carburetors run about 5.5 percent richer at mile-high Denver than they do in Detroit, and an additional metering error is caused by earlier opening of the power enrichment valve at high altitude. Researchers are considering ways to minimize or eliminate these errors in metering.

Professor Bolt has evaluated the effects upon metering of changes in fuel properties, including viscosity, gravity, and composition. In general, the effects are small.

A fuel-flow stand constructed for Professor Bolt's project permits precise measurement of the fuel and air passing through the fuel circuits of typical carburetor metering elements. This apparatus also allows measurement of the air passing into the air bleeds. Research with the fuel-flow stand should provide a fundamental understanding of the two-phase flow phenomena in carburetors. Two-phase flow, resulting from the presence of air bubbles in the fuel passages, greatly affects metering. A computer simulation of the flow phenomena is being developed to predict the carburetor mixture ratio.

Investigators also have studied the pulsing nature of the flow, caused by the irregular induction of the piston engine, which also has important effects on carburetor performance.

Professor Bolt and his associates have experimented with a constant volume bomb to determine the effect of the fuel/air-charge motion relative to the spark plug upon the lean limit of combustion. They learned that an enrichment of 17 percent over the stagnant lean limit is required to ignite a mixture having a velocity of 50 feet per second. They have attempted to demonstrate these effects in a single cylinder research engine. Through their research, these investigators have attempted to establish the leanest practical mixture for automobile engines.

CHEMICAL ASPECTS OF AIR POLLUTION FROM KRAFT PULPING

Irwin B. Douglass
University of Maine, Orono, Maine

The principal source of atmospheric emissions in the manufacturing of pulp and paper is the kraft pulping process which accounts for more than 60 percent of total U.S. pulp production. Dr. Irwin B. Douglass, of the University of Maine, has investigated chemical factors involved in the control of kraft odors.

Using a semi-micro pulping technique, Dr. Douglass has established several facts about the chemical processes related to kraft odors:

1. The release of odors during the pulping process is a direct function of temperature, length of digestion, and concentration of sodium sulfide in the cooking liquor.
2. Hardwoods release more methyl mercaptan and dimethyl sulfide than softwoods during the cooking operation.

3. The primary reaction in the digester between sulfide ion and lignin produces methyl mercaptan. Dimethyl sulfide results from a secondary reaction between mercaptide ion and lignin. The amount of methyl mercaptan present reaches a steady-state condition when mercaptide ion is consumed as fast as it is formed.

A pyrolysis study revealed that the organic material in black liquor solids when pyrolized in the presence of elemental sulfur, sodium sulfide, or sodium thiosulfate converts 30 – 60 percent of the sulfur to hydrogen sulfide. This reaction helps to explain the release of great quantities of hydrogen sulfide from the recovery furnace at times of heavy overloading.

During the evaporation of black liquor in the multiple-effect evaporators, some methyl mercaptan is formed. No appreciable amount of dimethyl sulfide, however, seems to be formed in the evaporators. Dr. Douglass also has studied the destruction of the malodorous sulfur compounds by means of chlorine and ozone.

Another aspect of the work has been concerned with the fundamental chemistry of low-molecular-weight organosulfur compounds. Methyl mercaptan, CH_3SH, is converted by chlorine and other reagents into methanesulfenyl chloride, CH_3SCL, and other compounds such as CH_3SCL_3, $CH_3\overset{\oplus}{S}CL$, and $CH_3\overset{\oplus}{S}OCH_3$. The spontaneous decomposition of these compounds and their general mode of chemical behavior have been under investigation.

CATALYTIC MECHANISMS FOR NITROGEN OXIDES REDUCTION

Max S. Peters
University of Colorado, Boulder Colorado

Dr. Max S. Peters has been attempting to develop a selective and highly effective catalyst for nitric oxide decomposition or reduction that could be used for abatement of air-pollution-causing nitric oxide in waste gases.

Research has concentrated on the catalytic activity of pyrolyzed polyacrylonitrile, an organic semiconductor with significant catalytic properties for reduction reactions. Dr. Peters has made a detailed study of its heterogeneous catalytic activity for the dehydration of tertiary butyl alcohol. The results of this study interpreted on the basis of a Langmuir-Hinshelwood mechanism, show that the reaction rate is affected significantly by adsorption of the products. A model based on a single-site or dual-site reaction-controlling situation produced results correlating well with experimental results.

Researchers have investigated the decomposition of nitrous oxide over polyacrylonitrile and over nickel oxide and have conducted conductivity studies of various organic semiconductors to obtain correlating factors for electron-transport mechanisms of catalysis.

INTERACTION OF FLUE GASES WITH CARBON SURFACES

P. L. Walker
The Pennsylvania State University, University Park, Pennsylvania

The chemisorption of SO_2 on an oxygen-free carbon surface has been examined over the temperature range 50° through 650° C in a research project under direction of Dr. P. L. Walker at Pennsylvania State University.

Charcoal chemisorbs approximately 1.0 percent of its weight in SO_2 at all temperatures in the range 50° through 300° C. Physically sorbed SO_2 is 3.0 percent at 50° C, 1.0 percent at 100° C, and approximately 0.3 percent at 150° C.

After the charcoal is saturated with chemisorbed SO_2, temperatures in excess of 650° C are necessary for regeneration of the charcoal in flowing helium to restore completely the original chemisorption capacity. Regeneration at 500° C results in SO_2 chemisorption capacity of no more than 0.3 percent; regeneration at 650° C results in a capacity of 0.8 percent. Chemisorption is 1.0 percent when the charcoal is regenerated at 950° C. The major weight loss during regeneration occurs above 600° C; below this temperature weight loss is no more than 0.2 percent, while at 950° C, it is approximately 1.0 percent.

CO and CO_2 are the only gases evolved, apart from traces of SO_2 sometimes detected from 300° through 400° C. Carbon monoxide first appears at about 300° C, and CO_2 at 500° C. Although CO_2 predominates between 600° and 700° C, at 800° C it practically disappears, probably because of reaction with the bed. Because only CO appears at the higher temperatures, the total weight loss following regeneration up to 950° C is mainly due to CO evolution. The apparent absence of any sulfur compound in the gas evolved during regeneration is thought to be due to condensation of evolved sulfur on the cooler surfaces of the absorption column. Since the whole column is weighed in determining weight loss, sulfur loss from the bed would not be detected.

Regeneration of the charcoal at 650° C restores approximately 80 percent of original sorption capacity. In a subsequent sorption experiment at this temperature, SO_2 was continuously chemisorbed and reduced to elemental sulfur which freely condensed on the cooler surfaces of the adsorption column. The experiment continued for 7 hours with complete removal of SO_2 from the gas stream and no indication of any loss in bed reactivity. At this temperature, both CO_2 and CO were present in the gas leaving the bed, the CO_2/CO ratio varying from 2.7 after 36 minutes to 4.0 at the end of 7 hours. The increasing CO_2/CO ratio was attributed primarily to a decreasing CO concentration leaving the bed. Most of the CO appearing was considered a primary product since the reaction between CO_2 and the bed to produce CO is very slow at 650° C.

Of the total weight loss observed during regeneration up to 950° C following adsorption at 50° through 300° C, approximately 63 percent occurs above 700° C. This stage of the regeneration, however, apparently does not appreciably enhance the sorption capacity of the charcoal, which is already 80 percent restored at 650° C. Regeneration of so much of the original capacity and reduction so readily of SO_2 to elemental sulfur at 650° C, suggest that the essential stage in regeneration is the removal of sulfur from active sites on the charcoal surface.

CRYSTAL STRUCTURE DETERMINATION OF STABLE OZONIDES

James L. McAtee, Jr.
Baylor University, Waco, Texas

In his research into the physiological aspects of ozone in the air, Dr. James L. McAtee, Jr., at Baylor University, has investigated crystal structures of organic ozonides of substituted indones. Determination of these structures will increase understanding of the chemical and physical properties of such compounds with regard to their physiological behavior.

The organic ozonide, di-tert butyl cyclopentene–1,2 dicarboxylate ozonide, was the initial compound studied by crystal-structure methods. Dr. McAtee found that this material crystallizes in the monoclinic system with A equaling 15.39°, B equaling 10.40°, C equaling 11.19° and γ equaling 104.5°, with the C-axis as the unique axis. Each unit cell contains four molecules. Utilizing crystal-graphic data obtained from the Buerger precision camera and the Weisenberg camera, Dr. McAtee determined the space group to be P2/B. The atomic positions for this compound have been evaluated by means of a high-speed computer.

GAS PHASE KINETICS OF KRAFT MILL POLLUTANTS

F. E. Murray
British Columbia Research Council, Vancouver, British Columbia, Canada

In his research into the reactions of sulfurous air pollutants, Dr. F. E. Murray, of the British Columbia Research Council, found that at about 800° C methyl mercaptan, dimethyl sulfide, and dimethyl disulfide could be oxidized over iron that has been preoxidized on the surface of the particles. This finding was the basis for a mill experimental reactor. Promising results achieved with the experimental reactor, in turn, led to plans for a full-scale catalytic unit at a pulp mill.

In his laboratory work, Dr. Murray has studied the oxidation in solution of methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. This work included studies of the oxidation of dimethyl disulfide in alkaline solution with molecular oxygen. These studies could lead to a process for rendering contaminated kraft mill condensates suitable for use in the mill's hot water system which would not emit air pollutants at the point of reuse.

BOUNDARY LAYER FLOW IN ELECTROSTATIC PRECIPITATORS

S. L. Soo
University of Illinois, Urbana, Illinois

The research directed by Dr. S. L. Soo concerns removal of particulate pollutants from air by electrostatic precipitation. Aspects of this process under investigation include the nature of boundary layer flow in an electrostatic precipitator passage, the effect of boundary layer flow on collection rate and reentrainment, the density distribution of particles in passages, and the interaction between electrostatic forces and turbulent diffusion.

Dr. Soo has introduced and verified a differential procedure of isokinetic sampling from a particulate suspension. This procedure eliminates error due to holdup in the sampling system and corrects for depletion in a finite system.

This research also has resulted in invention of an improved fiber optic probe with signal multiplication. Simpler and more rugged than a photometer, this probe makes possible measurement of density of a dilute aerosol suspension on the basis of either absorption or scattering of light from a light source to a photocell.

Formulation of electro-aerodynamics and correlation of experimental data on suspension should lead eventually to rational design and scaling of electrostatic precipitators.

In flow passages of a conventional electrostatic precipitator, the secondary flow due to electric wind was found to be a basic cause of reentrainment in the conventional design. Since this effect cannot be eliminated in the conventional plate-wire system, a significant change in design is necessary for further improvement in precipitator efficiency.

ENGINE EMISSION REDUCTION BY COMBUSTION CONTROL

Wolfgang E. Meyer
The Pennsylvania State University, University Park, Pennsylvania

In his study of engine emission reduction by combustion control, Professor Wolfgang E. Meyer has concentrated on development of experimental apparatus and techniques. He has made progress in instrumentation and has completed a unique exhaust gas sampling system designed to draw samples from only those engine cycles which have specific characteristics.

The sampling system examines each cycle and decides whether to issue a command to a sampling valve, in the exhaust line near the engine, to admit a sample to the gas analysis train. The system consists of (1) the transducers, which sense pertinent cycle characteristics (cylinder pressure, rate-of-pressure rise, flame front speed, crank angle, etc.); (2) the logic components, which compare the signals generated by the transducers to preset values to determine whether to issue a command; and (3) a sampling, or diversion, valve which is actuated by the commands.

This system is designed to identify those engine cycles that produce higher than average emissions of a selected species and to determine which cycle characteristics are associated with the production of particular exhaust-gas species and what the relationships are. This information should be valuable in designing the combustion process for minimum emissions, particularly during operation with lean fuel-air ratios at which cyclic variations are large.

REVERSIBLE METAL COMPLEXES WITH AIR POLLUTANTS

Lauri Vaska
Clarkson College of Technology, Potsdam, New York

Professor L. Vaska has discovered that certain transition metal complexes react reversibly with some important air pollutants, such as sulfur dioxide, carbon monoxide, and unsaturated hydrocarbons. To learn about the factors involved in these unusual reactions, this investigator has undertaken a systematic kinetic and thermo-chemical study of the reversible uptake of these gases by the complexes in solution.

These studies have revealed that the affinity of the molecules of these air-pollutants toward the complexes studied, e.g., $IrCl(CO)(Ph_3P)_2$, increases markedly in the order: $C_2H_4 < CO < SO_2$. The velocity of the uptake reactions and the stability of the resulting metal complex-gas adducts increase with increasing basicity of the original metal complex. The basicity is a function of the metal, its oxidation state, and the ligands present. These findings suggest that metal complexes might be designed for application as abaters of air pollution.

AIR TRANSPORT OF POLLUTANTS TO THE MARINE ENVIRONMENT

William J. Nolan
University of Florida, Gainesville, Florida

The purpose of Professor William J. Nolan's research was to determine the effects, in regard to air pollution, of solvent extraction of rosin from southern-pine chips before kraft pulping and neutral-sulfite semichemical (NSSC) pulping. Shredded chips were used throughout the project because rosin could be extracted from them more readily than from mill-size chips. Reduction of rosin content to less than 0.5 percent of dry wood was found to be impractical. In kraft pulping, rosin extraction caused a slight decrease in yield and physical strength of pulp.

Odoriferous noncondensibles in the cook were measured by a method involving determination of concentration of mercaptans and hydrogen sulfide in the black liquor just before the blow. Caustic absorption indicated concentrations of 20mg to 25mg H_2S and 50mg to 75mg mercaptans per liter of black liquor with standard deviations of about 10 percent for sulfide and 12 percent to 14 percent for mercaptans. A method for accurate determination of these concentrations could be a valuable tool for measurement of air pollution potential in the kraft mill.

Testing several black liquor samples from the experimental digesters, the investigator found no differences in amount and persistence of foam generated by pulping of unextracted slash pine, containing 3.5 to 4.5 percent rosin, or by pulping of extracted slash pine chips containing as little as 0.3 percent rosin. The fact that reduction of rosin content of the wood from about 4 percent to 0.3 percent did not reduce

foaming characteristics of the black liquor suggested that saponified rosin might not be the principal cause of foaming. Black liquor from hardwood digesters showed foaming characteristics identical to those of slash pine liquors. In another experiment, hardwood chips, a mixture of oak and gum containing negligible rosin, cooked in the laboratory digesters with kraft liquor, produced waste liquor just as foamy as all other liquors tested. Professor Nolan planned additional tests to increase the sensitivity of the method for detecting differences in foaming tendency.

Rosin extraction had no effect on neutral-sulfite semichemical (NSSC) pulping except for a slight increase in speed of pulping. After a few sets of experimental cooks demonstrated this lack of effect, further NSSC pulping experiments were concentrated on unextracted chips.

Physical strength of slash pine pulps in the yield range of 50 to 55 percent are about 5 percent lower in tear strength, but are comparable in burst and tensile strength to slash pine pulps of 45 to 50 percent yield. Lignin content of these NSSC pulps ranged between 11 and 15 percent while lignin content of kraft was about 6 to 8 percent. Slash pine NSSC pulps of 60 percent or higher yield were weaker in all strength categories than fully cooked kraft pulps, because of the very high lignin content (about 20 percent) of the NSSC pulps.

In this study, Professor Nolan found that an increase in the molal ratio of sodium sulfite to sodium carbonate from 3:1 to 6:1 increases screened yield. He has planned further research involving liquors made up entirely of sodium sulfite or mixtures of sodium sulfite and bisulfite, which may result in more rapid reaction, more selective lignin removal, brighter pulps, and, possibly, increased physical strength.

FUNDAMENTALS OF AIR CLEANING BY SORPTION PROCESSES

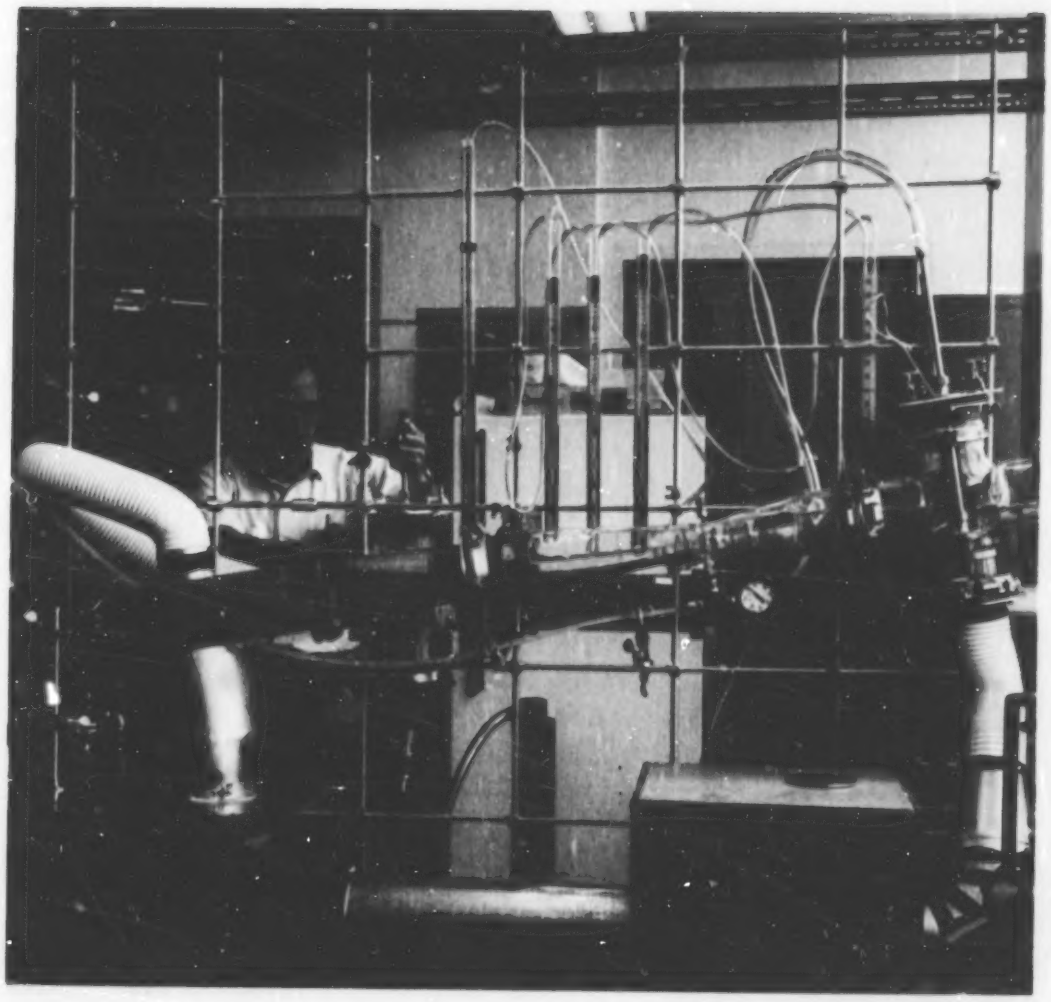
M. J. D. Low
New York University, University Heights, New York

Dr. M. J. D. Low, of New York University, has established the feasibility of monitoring smokestack effluents from distant ground locations by measuring the infrared emission spectra of the stack gases.

The small optical system of a multiple-scan interference spectrometer was mounted on an 8-inch reflecting telescope. Pointing the interferometer-telescope combination at a stack plume, investigators could record in minutes, at night, the spectral distribution of infrared radiation emitted by the effluent. The presence of SO_2 was readily detectable.

Such measurements, which can be carried out relatively easily, offer a novel instrumental approach to studies in air pollution.

Dr. Low also has developed techniques for recording of infrared spectra of samples of solids, liquids, and gases using the multiple-scan interference spectrometer. One-microgram samples can be examined in 1 or 2 minutes.



Mr. Dale A. Lundgren is shown with a Venturi scrubber, part of the apparatus used in the "Basic Study of Air Pollution Control Wet Scrubbing," research grant AP 00723-01. This particular equipment aims at developing a definition of the performance of low-pressure-drop gas scrubbing equipment for optimum efficiency.

COMMUNICATION

MANUAL OF METHODS FOR SAMPLING AND ANALYSIS OF AIR

A. C. Stern
University of North Carolina, School of Public Health, Chapel Hill, North Carolina

Professor A. C. Stern heads an intersociety committee supervising preparation of a manual of methods for ambient air sampling and analysis. The intersociety committee represents seven cooperating organizations: the Air Pollution Control Association, the American Conference of Governmental-Industrial Hygienists, the American Industrial Hygiene Association, the American Public Health Association, the American Society of Mechanical Engineers, the American Society for Testing and Materials, and the Association of Official Analytical Chemists. This committee supervises the project and serves as an editorial board.

The committee plans to provide standard methods for examination of air comparable to those already available for examination of water and liquid wastes. Methods will be detailed in a standard format: (1) principle of the method, (2) range and sensitivity, (3) interferences, (4) precision and accuracy, (5) apparatus, (6) reagents, (7) procedures, (8) calibration, (9) calculation, (10) effects of storage, and (11) references. Pollutants to be considered were classified arbitrarily into eight substance categories: (1) sulfur compounds, (2) halogens, (3) oxidants and nitrogen compounds, (4) carbon compounds, (5) hydrocarbons, (6) metals I, (7) metals II, and (8) radioactive substances.

A seven-member substance subcommittee, with one representative from each participating society was appointed for each of the eight substance categories. An additional subcommittee is responsible for common sampling procedures, common laboratory techniques and precautions, specifications for supplies and materials, and guidelines for evaluation of automatic equipment. Methods recommended by a subcommittee are checked by the editor and, if accepted, are sent to the intersociety committee. If approved by the committee, the method is made available for publication as a tentative method and is referred to a separate coordinating organization for collaborative testing. Only after thorough testing by a number of laboratories is a method considered standard. The intersociety committee hopes to have published in 1970 tentative methods for all listed compounds.

The project is expected to provide a sound basis for improvement of methodology over a period of years. The most direct benefits of the manual, however, will be in field monitoring and evaluation. It will make possible comparisons of pollution levels in different areas and will aid in the development of air quality criteria and standards.

AUDIOVISUAL METHODS FOR AIR POLLUTION INFORMATION

Murdock Head
George Washington University Medical Center, Warrenton, Virginia

A research project being conducted by Dr. Murdock Head, of the George Washington Medical Center, is intended to facilitate public dissemination of air pollution information. Dr. Head is investigating current air pollution information dissemination programs, the measures of effectiveness being used, interrelationships among programs, quality of programs, intent and presentation of programs, and the breadth and integration of information coverage. A second part of the project is a study of information collection, correlation, storage and retrieval, and distribution.

The research group produced a documentary film evaluated in cooperation with medical and civic groups across the country as a means of bringing air pollution information to the public. The film, "Beware The Wind," achieved wide acceptance and was used by community leaders to develop air pollution control

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groups. Requested for showing throughout the country, it has been used by conservation groups, community groups, and professional societies. As a television presentation, it was awarded the Television Academy Public Affairs Emmy for the Best Documentary film of 1967.

A second film, "Eagles Lament," treats air pollution as viewed from the air through the eyes of professional pilots. The third film to be produced by Dr. Head's group, "Battle Below the Clouds," will show what civic and professional groups can do about air pollution in a typical American city.

The effectiveness of the films as a means of dissemination of information will be evaluated by means of questionnaires, interviews, and critical reviews by professional critics and professionals in air pollution control.

COMEX–AIR POLLUTION COMPUTER RESEARCH PROJECT

Knud W. Leffland
University of Southern California, Los Angeles, California

Pollex, a management-education game under development by the School of Public Administration, University of Southern California, will be a major element in the Air Pollution Control Institute of the School and is expected to be used throughout the country as it is developed and refined beyond its prototype stage. The Institute, established to prepare students for careers involving the planning, supervision, and management of air pollution control, deals with the decisions, operations, interpersonal relationships, planning, supervision and management required of an air pollution control executive/administrator.

The major project of COMEX, Dr. Leffland's computor research project, the game Pollex compresses realistic experience in the execution of responsibilities concerning air pollution. It takes into account the social, economic, demographic, and political factors encountered in a major city. The compression of experience takes place through interaction with a computer simulation of the environment into which decisions are fed and from which responses are received that reflect the critical changes effected by these decisions. The simulation interlocks over 30 submodels of the general model. Each submodel, simulating one component of the total system, such as property tax base, per capita income, or demand and supply of public services, processes the new information of the last decision and signals inputs to other submodels appropriately influenced. The submodel also may receive inputs from other submodels, either at a different time or simultaneously.

The modular structure provides unusual flexibility. Submodels may be easily added to incorporate more of the ecological system or additional factors, such as the fouling of a river occasioned by installation of a scrubber. Earlier management games based upon the urban setting have been much simpler and have lacked the electronics simulation of Pollex. Dr. Richard D. Duke of the University of Michigan, who developed Metropolis, one of the most widely used earlier games, is a co-investigator with Dr. Leffland of the COMEX project.

Inputs to the computer simulation are provided not only by the role of an air pollution control officer but also by a politician and an industrialist. Personal interactions take place among the three role players as part of the decision-making experience. Numerous actions by each role player may be taken during each cycle, or year, and several cycles are possible during a single day.

Team players in action. Video-taped pictures of an air pollution control officer and staff, Mayor and council, and an industrialist team in the management-education game "Pollex" now under experimental development with a research grant to the School of Public Education, University of Southern California.

INFORMATION ABOUT THE RESEARCH GRANTS PROGRAM

The National Air Pollution Control Administration provides support through research grants to assist nonprofit institutions and individuals to establish, expand, and improve research in air pollution control. No limitation has been established on the number or dollar value of research grants to an investigator or institution. Although matching funds are not required, current legislation does require that the grantee participate in the cost of the research project.

The Administration is concerned with all aspects of research and development related to the causes, effects, extent, prevention, and control of air pollution with respect to human health, welfare, and productivity. Grants are available to support the establishment of air quality criteria for all hazardous air pollutants and the development of more effective means for prevention and control of air pollution.

Research projects in the following areas of investigation may be considered for research grant support:

I. Effects of Air Pollution.
Includes effects on man, crops, livestock, materials, and the ecology in general. Effects are categorized as follows:

A. Effects of Air Pollution on Man and Experimental Animals.

1. Epidemiological and statistical studies on the relationship between air pollution and mortality and morbidity.
2. Effects of air pollution on broncho-pulmonary physiology and pathology.
3. Relationship of air pollution to broncho-pulmonary diseases such as lung cancer, emphysema, asthma, chronic bronchitis, and other related respiratory disorders.
4. Studies of aeroallergens and naturally occurring irritants and their sources, prevalence, seasonal variations, and effects on man.
5. Physiologic effects of specific known or suspected air pollutants.
6. Subjective and behavioral responses to air pollution.

B. Effects of Air Pollution on Agriculture and Livestock.
Includes effects on livestock, on the general ecology, and on plants at the macroscopic, cellular, and molecular levels. Specific pollutants of interest include sulfur oxides, ozone peroxyacyl nitrate, fluoride, and dusts.

C. Effects of Air Pollution on Materials.
Includes effects on plastics, metals, textiles, rubber, and building materials.

II. Economic, Social, and Political Studies.
Includes estimates of damage by air pollution, cost of air pollution control, studies of urban planning and land use, political aspects of control programs, attitudes of people towards air pollution, and methods for influencing public opinion.

III. Sources of Air Pollution and Their Controls.

A. Combustion.
Investigation of the combustion process and of emissions from incinerators, open burning, and solid waste disposal.

B. Automotive Emissions.
Studies of reactions of gases within combustion engines, of subsequent interactions in the atmosphere, of effects of operating conditions on emissions, and of methods for reducing emissions.

C. Industrial Emissions.
Includes investigations of industrial stack plumes, noxious odors, and particulate matter from industrial sources, such as paper mills, steel mills, rendering plants, chemical plants, nuclear fuel processing plants, and power generating plants.

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D. Development of General Control Principles and Devices.
Includes research into principles of control and development of devices applicable to control of air pollution. Control methods include static precipitation, scrubbing, sorption, and catalytic removal.

IV. Atmospheric Studies.

A. Physicochemical Characteristics of Air Pollutants.
Studies of gaseous, liquid, and particulate components of the atmosphere, and of the chemistry, thermodynamics, and kinetics of their formation and interactions as well as studies of the physics of aerosols.

B. Meteorology.
Studies of transport and diffusion of air pollutants (including radionuclides and pesticides), air pollution forecasting, biometeorology, and the influence of air pollution on visibility.

V. Analytical Technology.
Development of methods for analyzing and characterizing gases, liquids, and particulate matter.

VI. Communication.
Support of grants aimed at providing detailed technical and scientific information for the buildup of a base of practical knowledge for all interested parties.

A research grant application should be submitted jointly by the investigator and the institution sponsoring his research. Responsibility for fiscal and administrative management should be assumed by the institution.

To be eligible for support, a proposed project must receive favorable recommendation from a review panel of experts in appropriate fields. The panel considers scientific merit, qualification of the applicant, and adequacy of facilities. Each project is further evaluated as to its relevance to the program and its consonance with public policy. Approved projects are funded in accordance with their assigned priorities and the availability of funds. If not funded in a given fiscal year, an application may be carried over to the next fiscal year or, if the applicant wishes, may be withdrawn.

Recently the program has been expanded to provide limited support for feasibility studies and for young investigators who have stimulating ideas but little research experience. Applications are now being accepted for the exploratory support of appealing but high risk ideas and enthusiastic but untried investigators. These applications require the same forms, processing, review, and approval procedures employed for regular research grants.

In general, exploratory grants will be awarded for a maximum of $10,000 (including indirect costs) and 18 months, with a possible administrative extension to 24 months when warranted. Applicants may apply for a grant in this exploratory category, or the review groups concerned may elect to recommend an exploratory grant in lieu of a regular research grant.

Details concerning application procedures, application forms, and dates for submission of applications may be obtained from the Office of Research Grants, National Air Pollution Control Adminstration, P. O. Box 12055, Research Triangle Park, North Carolina 27709.